Information Communication Technology as a Cognitive Tool to Facilitate Higher-order Thinking

by

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Summary

Title:	Information Communication Technology as a Cognitive Tool to Facilitate Higher-order Thinking
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Digital educational technology is capable of contributing supplementary strategies that can be used to address various educational challenges faced by higher education. Foremost among these challenges is the widespread lack of academic preparedness of students who enter South African higher education institutions. The legacy of Apartheid, teachers' poor domain knowledge and command of the language of instruction, together with a lack of commitment to the cognitive development of learners are some of the reasons why students have not developed the cognitive skills required to engage in meaningful learning.

Meaningful learning requires a high level of conceptual engagement and development. To assist in the learning process, educators must focus on student learning rather than on the instructor and the technology used in the instruction. A powerful means of supporting meaningful learning is through a process of model building. Computer technology can effectively be used to facilitate the building of conceptual models. By encouraging students to use computer technology to build models that represent their personal understanding, the students are performing the role of designer and the technology is used as a cognitive tool. Using digital technology as a cognitive tool allows students to engage in critical thinking and higher-order learning. An expert system shell is one way in which technology can be used as a cognitive tool. When students build expert systems they are required to demonstrate the reasoning of an expert and to exhibit an understanding of causal relationships and procedural knowledge. There is very little evidence of

research concerning the application of expert systems as a cognitive tool in education.

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.

The conjectures and principles formulated during this study are expressed in terms of the characteristics, procedures and arguments associated with a learning environment that uses technology in the form of an expert system shell to facilitate higher-order thinking. These conjectures and principles were separated into seven interrelated clusters that can be summarised as follows:

- Initial exposure
- Guided discovery learning
- Designing the expert system on paper
- Creating domain awareness
- Linking conceptual understanding to a representation of that understanding
- Hands-on development
- Problem engagement

These conjectures and principles could guide similar endeavours undertaken by lecturers or instructional designers.

Keywords

Cognitive tools
Conceptual models
Constructivist learning
Critical thinking
Design principles
Educational technology
Expert system shell
Higher-order thinking
Modelling
Problem- solving

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List of acronyms

AI	Artificial Intelligence
CAD	Computer Aided Design
CAQDAS	Computer Aided Qualitative Data Analysis Software
HOT	Higher Order Thinking
HOTS	Higher Order Thinking Skills
ISD	Instructional System Design
PBL	Problem Based Learning
TUT	Tshwane University of Technology
ZPD	Zone of Proximal Development

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.

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 behaviorism 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 behiorism 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

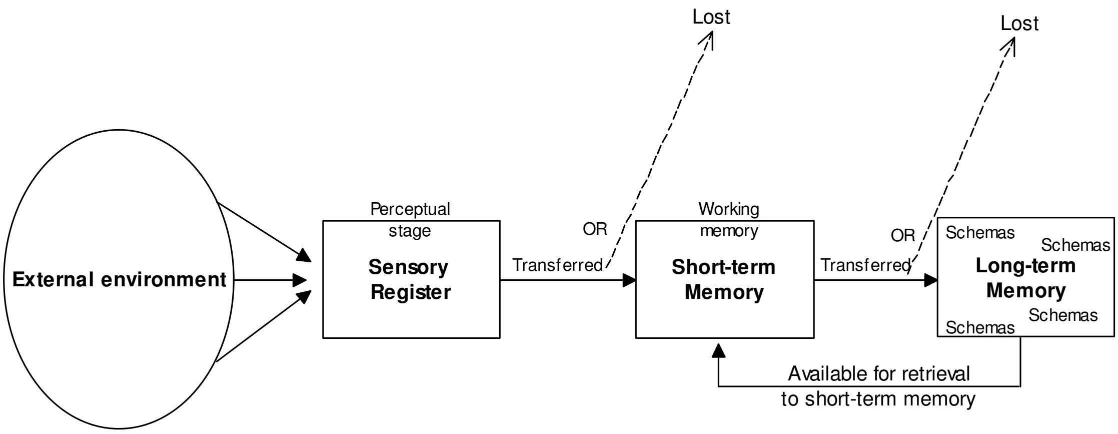

Figure 2.1 Stages of information processing according to the information processing approach to learning

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).

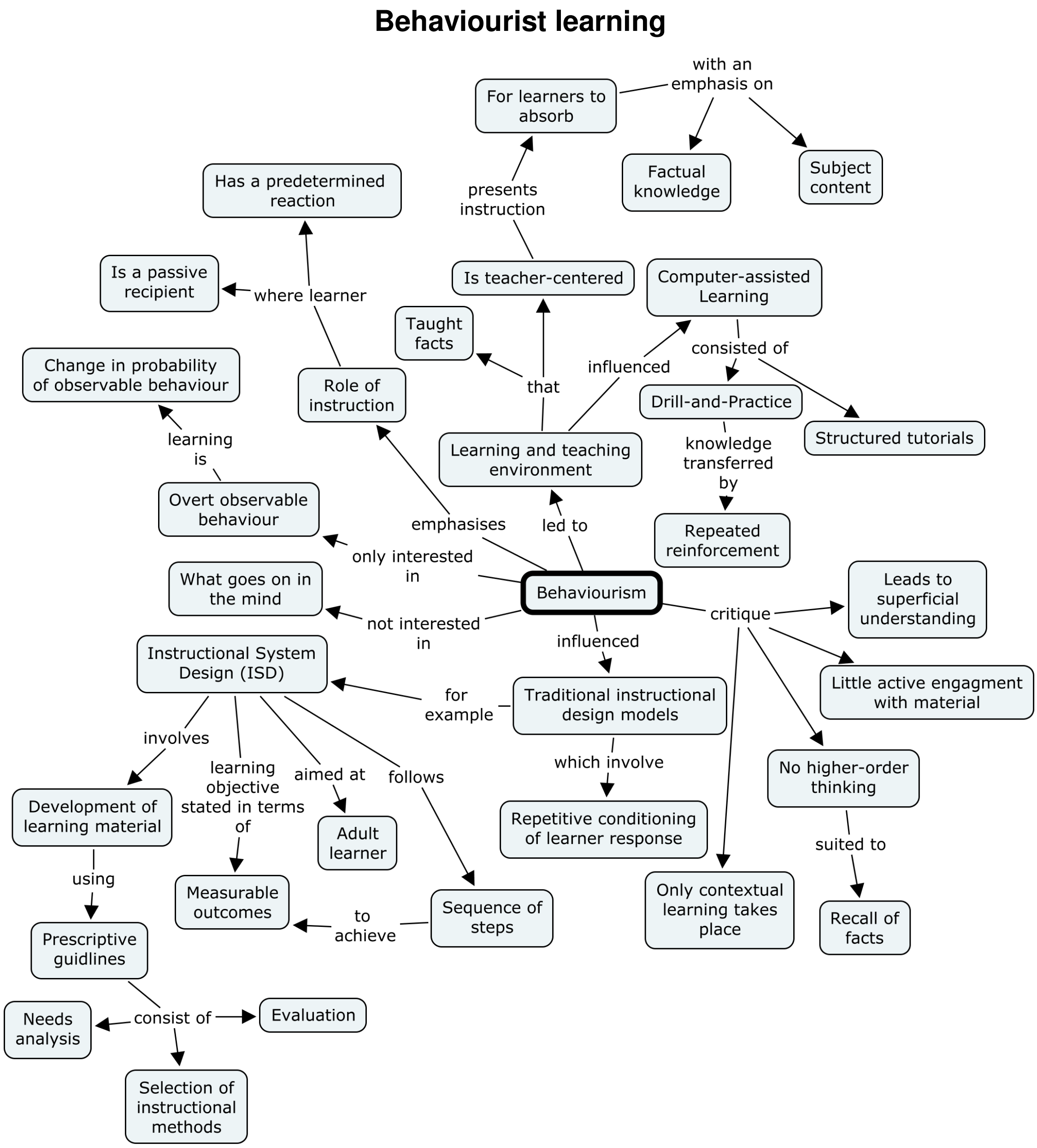

Figure 2.2 A synthesis of behaviourist-based learning

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.

Cognitivism

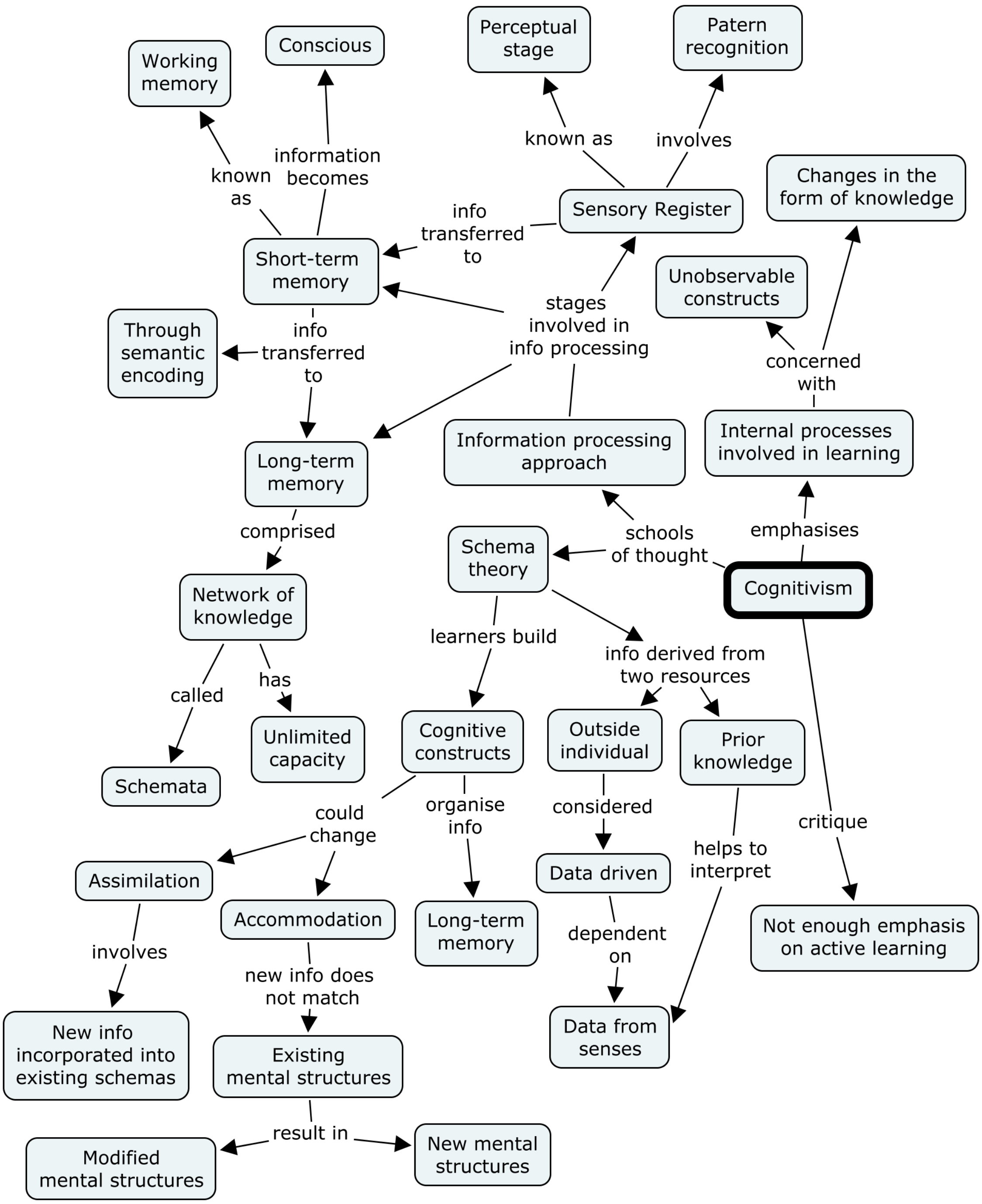

Figure 2.3 A synthesis of cognitivist-based learning

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.

Constructivism

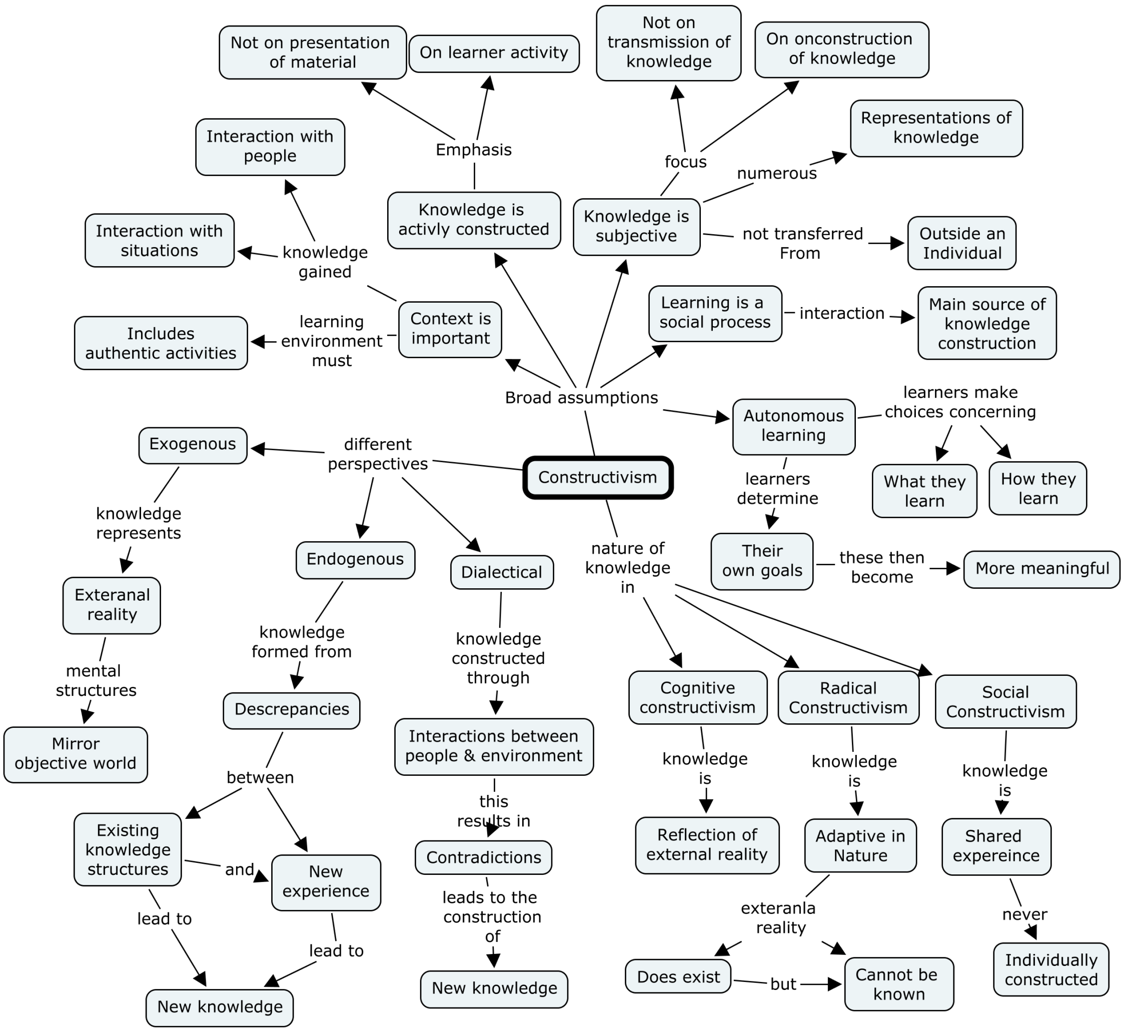

Figure 2.4 Synthesis of constructivism

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.

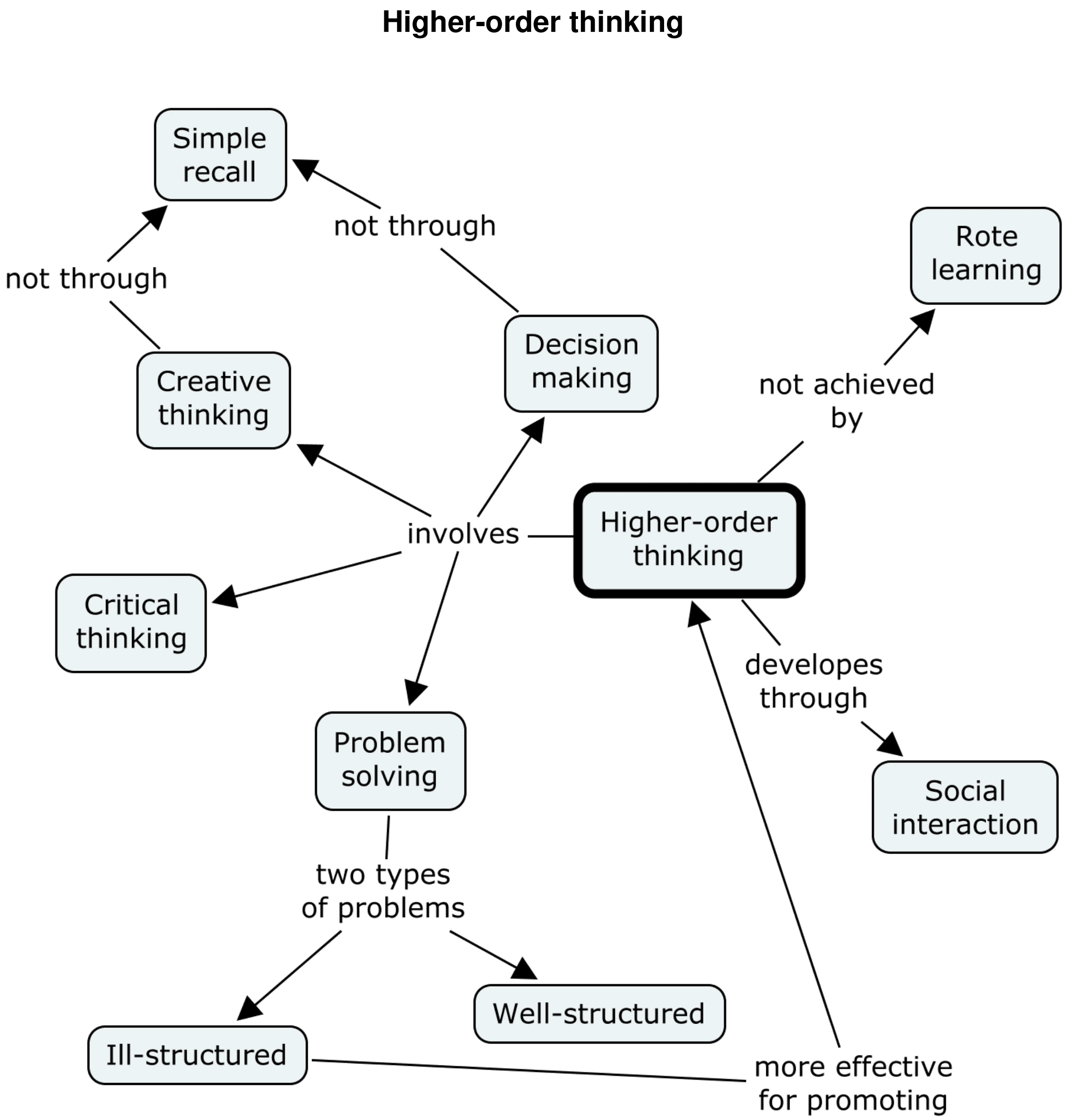

Figure 2.5 A synthesis of higher-order thinking

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.

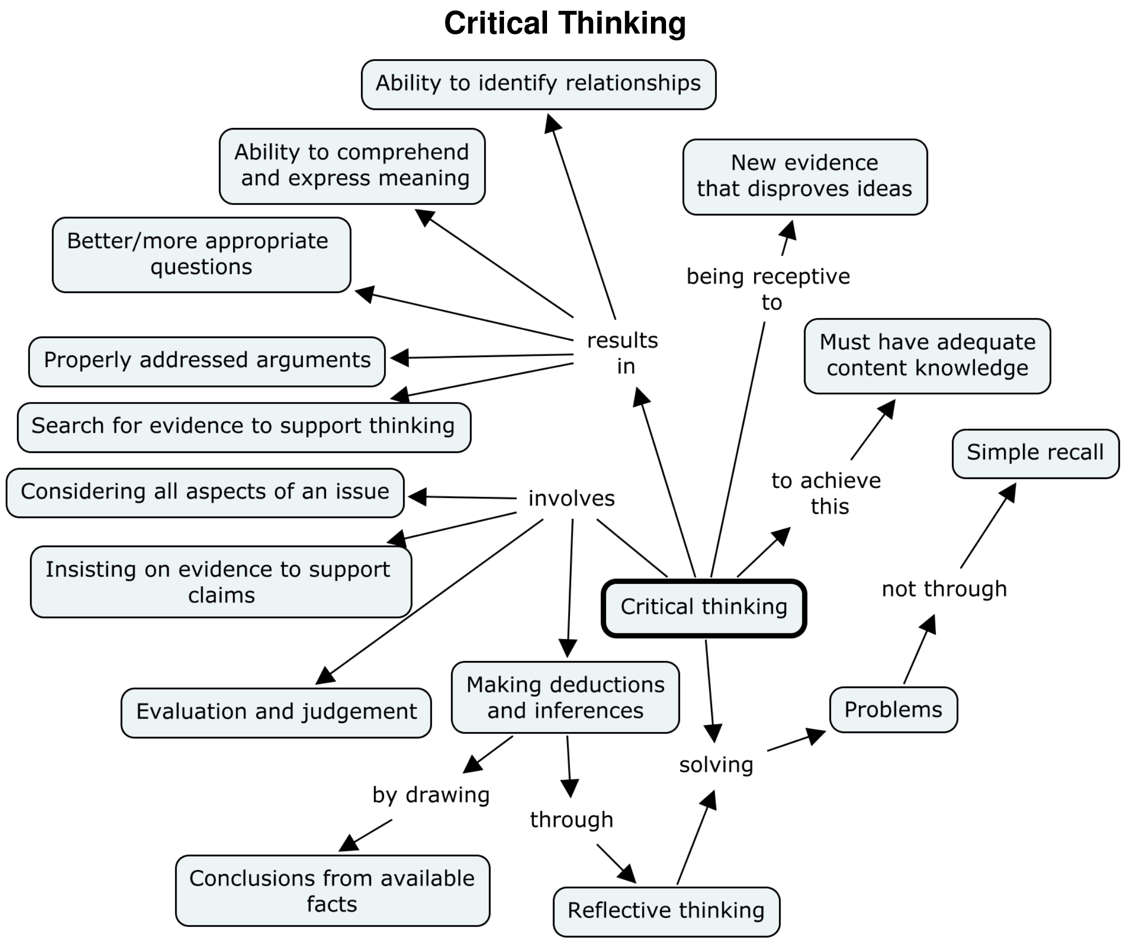

Figure 2.6 A synthesis of critical thinking

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

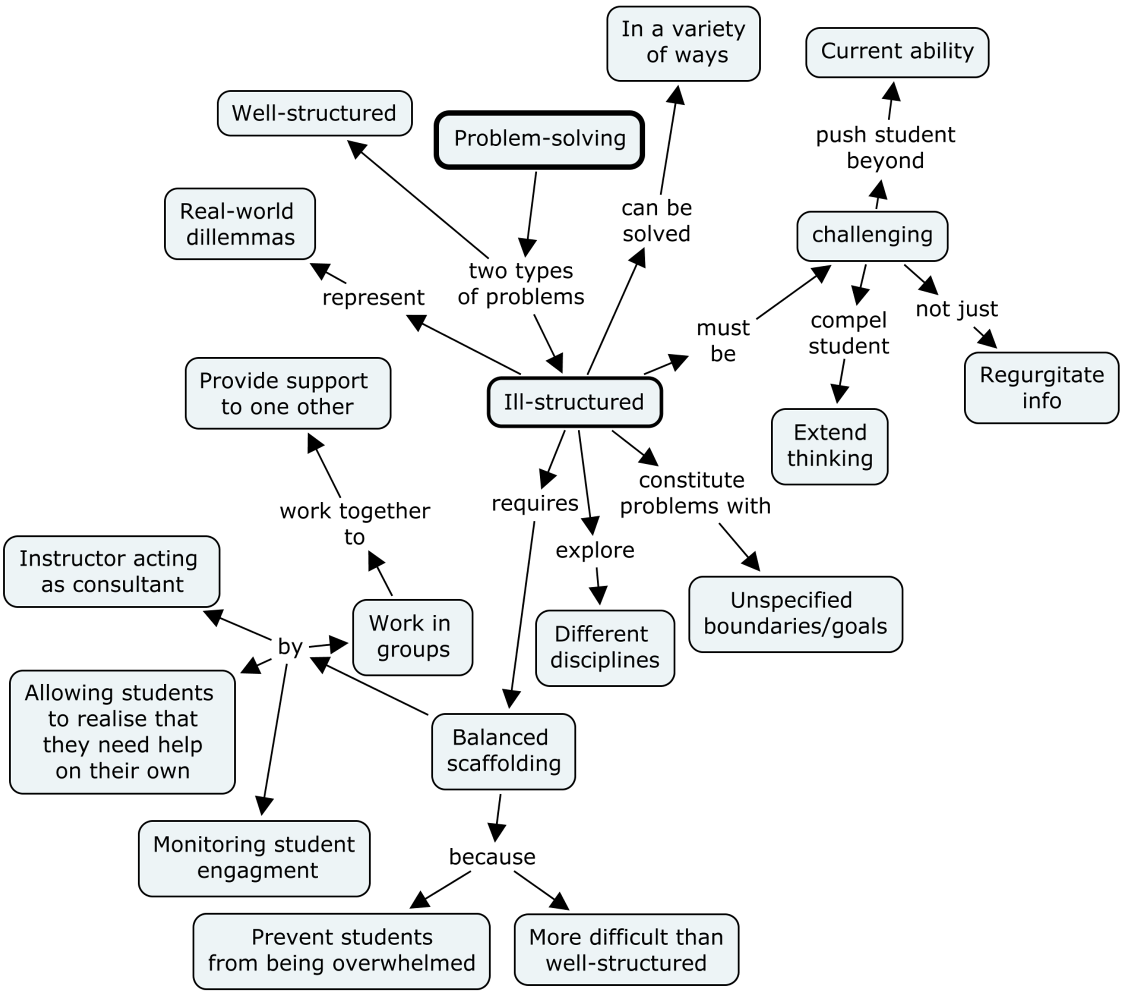

Figure 2.7 A synthesis of problem-solving

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

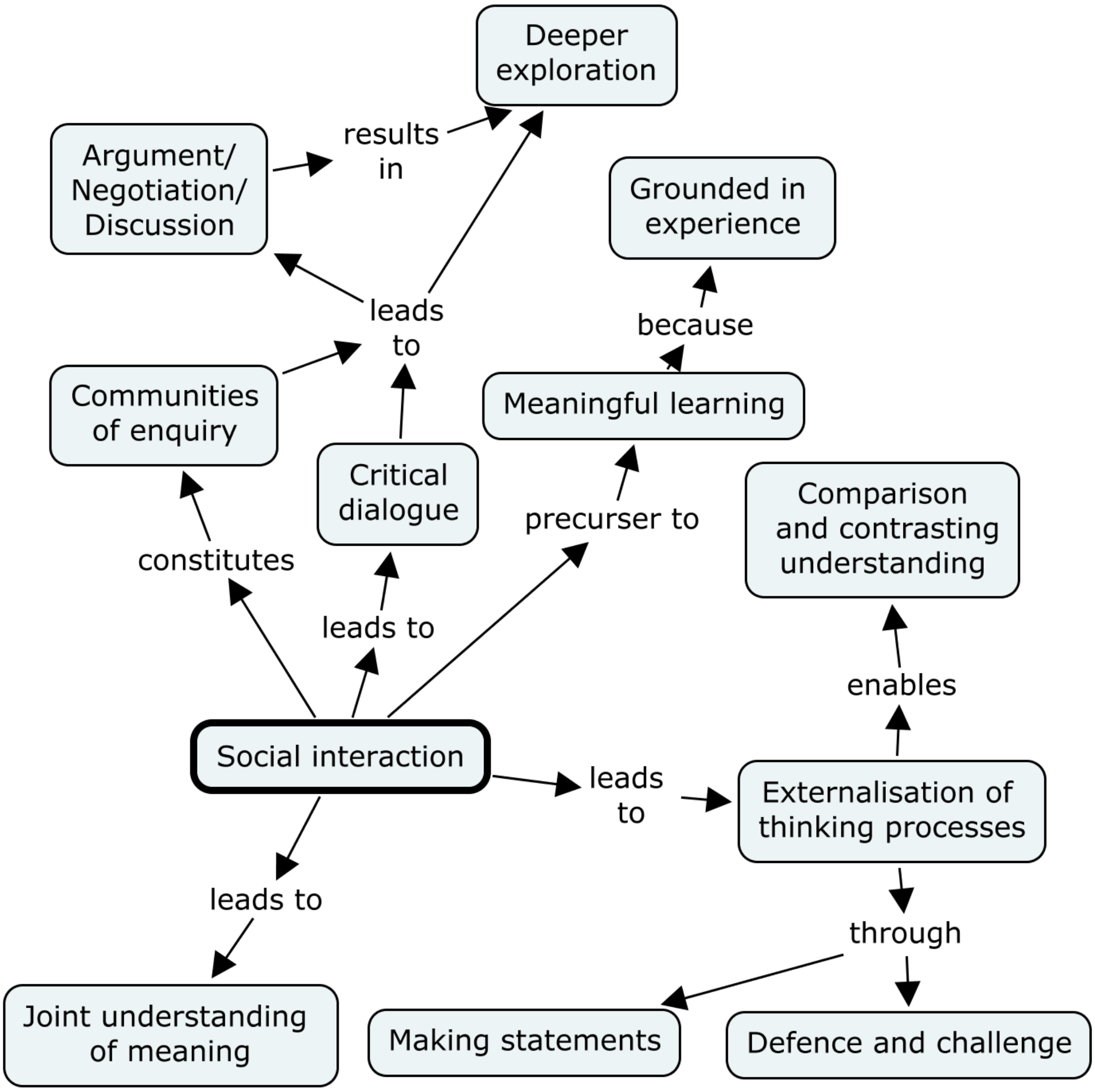

Figure 2.8 A synthesis of higher-order thinking and social interaction

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.

Chapter 3

Research design and research methods

This study aims at formulating design principles in the form of conjectures and principles and at exploring the experiences of students who have worked within a learning environment based on these conjectures and principles. The learning environment uses computer technology as a cognitive tool in the form of an expert system shell in order to facilitate higher-order thinking skills in students. This chapter discusses the research design and the methods used to formulate these conjectures and principles and to explore the students' experiences. The chapter begins with an outline of the philosophical worldview that frames the study and then goes on to outline in detail how a design-based research approach was adopted during the study. The sampling methods applicable to both sets of samples used in the research are explained, followed by a detailed explication of the data collection and analysis techniques employed. The chapter concludes with a discussion of the trustworthiness of the findings and the ethical considerations applicable to the study.

3.1 Philosophical worldview applicable to this study

Creswell (2009, p. 6) uses the term "worldview" to describe the "general orientation about the world and the nature of the research that the researcher holds". He points out that this encompasses "what others have called" (ibid.) paradigms, epistemology, ontology and methodology. The philosophical worldview adopted in this study is closely allied to the social constructivist worldview. In a social constructivist worldview the objective of research "is to rely as much as possible on the participants' view of the situation being studied" (Creswell 2009, p. 9). The meaning inherent in a particular situation is commonly determined through "discussion or interaction with other persons" (ibid.). In this worldview the generation of meaning is invariably social and results from "interaction with a human community" (ibid.). Focus group interviews were principally used as a data collection method during this study in order to explore "multiple viewpoints or responses" concerning a specific issue (De Vos *et al.* 2009, p. 300). The emphasis was to uncover a "socially constructed meaning of reality as understood by an individual or group" (Guo & Sheffield 2007, p. 675). Creswell (2009, p. 8) points out that a social constructivist worldview is often combined with interpretivism. Carcary (2009, p. 12) indicates that distinct from a more positivistic perspective, "physical-law-like generalisations are not the end product" of an interpretive approach. In contrast "understanding through detailed descriptions is sought by answering questions such as '*what*?', '*why*?' and '*how*?'". Qualitative research methods are emphasised within interpretivism "where words and pictures as opposed to numbers are used to describe situations" (ibid.).

3.2 Strategy of inquiry

Creswell (2009, p. 11) proposes that strategies of inquiry "provide specific direction for procedures in a research design" and he distinguishes three broad groupings in this regard: quantitative, qualitative and mixed method. This study adopted a qualitative strategy of enquiry using a grounded theory approach to data collection and analysis.

3.3 Design-based research

This study employs a research design that is based on many of the principles associated with educational design-based research (Discussed in detail in Chapter 2). Reeves, Mc Kenny and Herrington (2011, p. 56) state that educational design-based research is an effective method of "solving real problems in practice and to advancing theoretical understanding as well". This would allow the research to be more meaningful as it provides a direct association between research and practice (ibid.). Design-based research is considered particularly appropriate for the exploration of "technology-based initiatives" (Parker 2011, p. 1).

3.3.1 How this study employs educational design-based research

A review of the literature (Fisk & Ladd 2005; Stephen, Welman & Jordaan 2004; Thanosoulas 2001; McLaughlin 1999; Bothma, Botha & Le Roux 2004; Jaffer, Ng'ambi & Czerniewics 2007; Scott & Yeld 2008; Legotlo *et al.* 2002*;* Van der Berg & Louw 2006; Howie 2003; Ngidi & Qwabe 2006; Schlebush & Thobedi 2004) has established that students typically enter higher learning institutions academically under-prepared and are unable to employ higher-order thinking skills effectively when engaging with subject matter. A prototype of a learning environment that uses technology as a cognitive tool in the form of an expert system shell was designed, using the researcher's creativity as well as by referencing the appropriate literature in this regard. This learning environment aimed at facilitating higher-order thinking skills in Foundation English Communications Skills students at TUT. It was considered to be a part of a "proposed solution" (Herrington *et al.* 2009, p. 129) to the academic under-preparedness of these students. A design team comprising experienced English Communications lecturers as well as instructional designers was presented with this provisional design of a learning environment in order to facilitate a process of improvement and refinement of the environment. Ten contact sessions were held with this design team with the researcher making "adjustments and improvements" (ibid.) after each session. The sessions came to an end when the proposed learning environment was generally considered to be ready for implementation in an authentic educational setting.

3.4 Sampling methods

A purposive sampling method was used in the selection of members of the design team and simple random sampling was used to select a sample from the student population.

3.4.1 Purposive sampling

When choosing purposive sampling the researcher samples with a purpose in mind (Trochim 2001, p. 56). White (2005, p. 120) indicates that purposive sampling is undertaken on the "basis of the researcher's knowledge of the population" and as a result of this knowledge a considered decision is made concerning which individuals to select in order to "provide the best information to address the purpose of the research" (ibid.). Purposive sampling involves the researcher making a critical assessment concerning the characteristics and attributes of the population and then selecting the sample accordingly (De Vos *et al.* 2009, p. 329). Members of the design team, that was assembled in order to design a learning environment that uses technology as a cognitive tool to develop higher-order thinking, were selected using a purposive sampling method. This design team consisted of six individuals with two distinct professional backgrounds. Two of the members were instructional designers from the Teaching and Learning with Technology (TLT) department at the Tshwane University of Technology (TUT); the remaining four individuals were all English Communication Skills lecturers at TUT. This team provided the researcher with a suitable blend of experience and skill in the field of educational technology as well in the teaching of English Communication Skills, which constituted the subject domain of the learning environment. The ten design sessions were all conducted at the Pretoria West campus of the Tshwane University of Technology.

3.4.2 Simple random sampling

To explore how the students experienced the learning environment that was based on the conjectures and principles formulated during this study, a sample was selected from the student population using a random sampling method. White (2005, p. 118) proposes that a simple random sampling technique include any method "that provides each population element an equal probability of being included in the sample". Each student in the population was assigned a number and then a table of random numbers (ibid. p. 121) was used to select two focus groups of eight participants each.

The population consisted of 140 students from the Tshwane University of technology who were enrolled for a diploma course in Information Communication Technology and registered for the Foundation English Communications Skills subject. The contact sessions were held at the Soshanguve South campus of the Tshwane University of Technology (TUT).

3.5 Data collection

Focus group interviews, held with the samples described in 3.4.1 and 3.4.2, were principally used as a data-collection instrument in order to gain comprehensive insight into their opinions and experiences. Focus group interviews are "semi-structured discussions" with groups of between 4 and 12 people for the purpose of exploring a particular set of issues (Tong, Sainsbury & Craig 2007, p. 351). It is good practice to ask broad questions related to the topic of the discussion initially before focusing on questions that are more pertinent to the study (ibid.). During focus group interviews participants are encouraged to interact with one another but the facilitator must ensure that they answer questions individually (ibid.). This interaction would allow respondents to "explore and clarify individual and shared perspectives" (ibid.).

Tremblay, Hevner and Berndt (2010, p. 600) propose two types of focus group in design-based research; these are "exploratory focus groups" that are used for the "design and refinement of an artefact" and "confirmatory focus groups" (ibid.) that are used to explore or confirm an artefact's value in an authentic setting. They consider focus group interviews to be an "appropriate evaluation technique for design research projects" for the following reasons:

- Focus group interviews are sufficiently flexible to accommodate a "wide range of design topics and domains".
- The researcher is placed in direct contact with potential users of the designed artefact as well as with domain experts. This enables the

researcher to obtain clarity concerning the designed artefact as well as pertinent design issues.

- Focus group interviews yield rich data that allows the researcher to gain a comprehensive understanding of issues discussed.
- Focus group interviews enable respondents to build on the comments of others (ibid.).

Ten focus group interviews were conducted with members of the design team and four focus group sessions, two per group, were conducted with the sample drawn from the student population. The ten focus group sessions conducted with the design team were held at the Pretoria West campus of the Tshwane University of Technology from 20 January 2011 to 4 March 2011. A relaxed and informal atmosphere was created during each of these focus group sessions where participants were free to help themselves to refreshments at any time during the interview. Each of the focus group interviews lasted between twenty and thirty-five minutes and on rare occasions certain group members were required to excuse themselves during the interview due to lecturing commitments. The researcher facilitated the focus group interviews and typically opened each session with very broad questions such as: *How did you experience what we did today?* Or, *What are your thoughts concerning what you experienced during this session?* The questions became more focused as ideas and opinions emerged from the discussions. Each of these interviews was recorded using a handheld cassette recorder; these recordings were later transcribed verbatim in preparation for analysis.

The focus group interviews conducted with the student sample were held at the Soshanguve South campus of the Tshwane University of Technology between April 2011 and June 2011. These focus group interviews were conducted midway through training and then again at the end of training. A relaxed atmosphere was created before each of the focus group sessions where the researcher reminded the students of the purpose of the research and that participation was completely voluntary. None of the students elected to leave and all of them approached the interviews with enthusiasm and a willingness to be included in the undertaking. The researcher facilitated the focus group interviews and initially used very general questions such as: *What are your impressions of the learning environment that we have been working in over the last few weeks?* Or, *How do you experience working in the learning environment*? These questions became more specific as ideas, opinions and experiences were expressed. Each of these focus group interviews was recorded using a handheld cassette recorder; these recordings were later transcribed verbatim in preparation for data analysis.

3.6 Data analysis

The data analysis of both sets of focus group interview transcriptions was undertaken using the grounded theory method of coding, sorting and analysing. The Computer-Assisted Qualitative Data Analysis Software application (CAQDAS), Atlas.ti, was used in order to make the analysis more versatile.

3.6.1 The use of Atlas.ti in preparing for data analysis

Making use of 'code and retrieve' software such as Atlas.ti inevitably allows a researcher to include much larger quantities of data in the research and makes the coding process "significantly less cumbersome and tedious" (Lu & Shulman 2008, p. 106). Using CAQDAS allowed the researcher to invest more mental energy in the analysis rather than in the technicalities and logistics of the research process (ibid.). Atlas.ti was used during the data analysis stage of this study to assist in the examination and interpretation of the focus group interviews described in paragraph 3.5. Each of the transcripts of the focus group interviews conducted with the design team was imported into the Atlas.ti environment separately as a primary document. Consequently there were ten separate hermeneutic units, separate Atlas.ti projects, involved in the analysis of the design team focus group interviews. This was done to preserve the context of each of the design sessions during the data analysis, which assisted the researcher in making sense of comments made by the members of the focus group.

Transcripts of all four of the focus group interviews held with the student sample were used as primary documents in the Atlas.ti environment to create a single hermeneutic unit to explore how students experienced the learning environment.

3.6.2 How the design team focus group transcripts were analysed

The analysis of the transcripts of all focus group interviews was based on the grounded theory method. This “consists of flexible strategies for focusing and expediting qualitative data collection and analysis" (Charmaz 2001, p. 675). The transcripts of focus group interviews held with the design team were coded using the software application Atlas.ti. (See Appendix F). Open coding was done, predominantly using a full sentence as the unit of analysis but fragments were also coded when this was considered appropriate. From time to time more than one sentence was grouped together under a single code when these together contained a discrete idea. This is in keeping with Zhang and Wildemuth's (2009, p. 3) assertion that qualitative content analysis typically uses "individual themes as the unit for analysis" that are not necessarily expressed in "physical linguistic units". The occurrence of a theme could be "expressed in a single word, a phrase, a sentence, a paragraph, or an entire document" (ibid.). Mainly descriptive labels were used during this phase of the coding process and often the words used by participants were used as labels. This is referred to as "in-vivo" in the Atlas.ti environment. Glaser (2002, p. 24) suggests that concepts are "in-vivo" when "they come from the words of the participants in the substantive area". Once this initial labelling had been done, and through a process of constant comparison, codes that contained similar central features or characteristics were grouped together to form more abstract higher-level categories. For instance, the higher-level category 'discovery learning' is made up of the following codes:

- Build on basic knowledge

- Trial and error
- Apply learning
- Battling on your own
- Sequence
- Hands on

These lower-level codes all seem to contain characteristics of discovery learning as a central idea or at least as a significant theme. It was commonly the case that a single low-level code was grouped more than once under a higher-level code or category. These codes were grouped together in "code families" using Atlas.ti. These code families were printed and then arranged in a table that has the following headings: category, codes, quote to support creation of category and comment (See Addendum A). This helped to establish groundedness and at times highlighted the necessity to regroup or rename codes/categories. The principle of constant comparison was central to this process. Wasserman, Clair and Wilson (2009, p. 359) point out that "the process of constant comparison brings data specific codes and broader concepts into an insight generating dialogue, as opposed to a simple grouping process".

To facilitate the formulation of design principles in the form of conjectures and principles, the format developed by Van den Akker (quoted in Plomp 2007, p. 17) in order to devise heuristic statements that are characteristic of design principles, was broken down into discrete parts. These parts were labelled 'characteristics (substantive emphasis)', 'procedures (procedural emphasis)' and 'arguments'. A table was then designed using 'category/codes', 'emergent characteristics (substantive emphasis', 'emergent procedures (procedural emphasis)' and 'emergent arguments' as headings for each column. (See tables 4.3-4.9, pages 166-212). The table formulated to establish or identify higher-level or more abstract categories was then closely examined in order to identify the emergent characteristics, procedures and arguments associated with each category. These emergent characteristics, procedures and arguments were organised in the appropriate table without regard for repetition, relevance or significance. Once all the higher-level categories formulated during the open coding process had been examined and organised in the table previously described, a process of reorganisation was undertaken. Design principles that could rationally be related to one another were grouped under the following headings:

- Initial exposure to the learning environment
- Handouts
- Discovery learning
- Design
- Subject (domain) awareness
- Representing understanding
- Development
- Problem interaction
- Sequence
- Scaffolding
- Examples

This reorganisation and grouping facilitated the filtering out of repetition and the discarding of principles that were considered insignificant and irrelevant. These reorganised characteristics, procedures and arguments were once again organised in a table with similar headings to the table described above but this time the design principles contained in it were not considered to be simply emergent from the data (See Appendix D). Once this table was complete descriptive paragraphs were formulated under the same headings mentioned above. This allowed for the relationship between the characteristics, procedures and arguments to be more clearly represented or articulated.

The process of identifying emergent characteristics, procedures and arguments, based on Van der Akker's heuristic formulation guidelines (quoted in Plomp 2007, p. 17), replaced the axial and selective coding stages more typically associated with grounded theory.

3.6.3 The process of analysing the student samples' focus group transcripts

Open, axial and selective coding techniques were employed in the coding, sorting and analysis of the transcripts of focus group interviews held with the sample drawn from the student population.

3.6.3.1 Open coding

De Vos *et al.* (2009, p. 341) propose that open coding involve the “naming and categorising of phenomena through close examination of the data". This basically involves "breaking down the data and identifying concepts embedded within individual statements" (Wasserman *et al.* 2009, p. 359). Transcripts of the focus group interviews that were held with the students were coded using Atlas.ti. The open coding was done in the same manner as described in 3.6.2. Once this initial labelling had been done, and through a process of constant comparison, codes that contained similar central features or characteristics were grouped together to form more abstract higher-level categories. For instance, the following descriptive labels or lower-level categories:

- Disagreement encourages thinking
- Have to think (reflect)
- Thinking logically
- Open mind
- Moving out of comfort zone
- Exploring own ideas
- Thinking at a higher-level
- Thinking like experts
- Thinking outside the box
- Understand the problem

were grouped under the higher-level code "thinking at a higher level [*sic*]" because they all had thinking more deeply or in a way that was not routine for the students as a central idea or characteristic. It was commonly the case that a single low-level code was grouped more than once under a higher-level code or category. For instance the lower-level code, "Disagreement encourages thinking", was grouped under the higher-level category "Thinking at a higher level [*sic*]" as well as under the higher-level category "Collaborating in groups".

All codes and categories identified during the initial stage of the open coding process were grouped together in "code families" using Atlas.ti. These code families were printed and then arranged in a table that has the following headings: category, codes, quote to support creation of category and comment. This helped to establish groundedness and at times highlighted the necessity to regroup or rename codes/categories.

3.6.3.2 Axial coding

Axial coding is a process that involves reassembling data in new ways after it has been fragmented during the open coding phase of the data analysis process (De Vos *et al.* 2009, p. 343). The relationship between the higher-order codes/categories and their related lower-order categories and codes were explored during the axial coding phase. A thorough analysis was performed around a single category at a time primarily with reference to the coding paradigm outlined by Corbin and Strauss (1990, pp. 423-424). Causal conditions that gave rise to the occurrence of the category/phenomenon were investigated, the phenomena themselves were established, attributes of the context were explored by examining the set of facts or circumstances that surrounded the phenomena, intervening conditions were investigated, action/interaction strategies that were formulated by the actors to handle the phenomena were explored and the consequences of these strategies were taken into consideration during this phase of coding.

For instance, intense analysis was performed around the higher-level code/category/phenomenon, "disagreement among group members". What caused this phenomenon to come about were the "group assignment" and the "different ideas" that were generated in the group. The circumstances that surrounded this phenomenon were the learning environment (i.e. laboratory sessions, non-laboratory sessions) and group discussions. The action/interaction strategies that students employed to handle the phenomena were mainly centred around attempts to "convince group members"," group decision making (vote)" and reflecting on one's own ideas. The consequences of these strategies were that "disagreement encourages thinking" and "leads to better end results" as well as "not getting the job done".

3.6.3.3 Selective coding

The main idea that emerged during the open and axial coding phases was centred on *working in a learning environment that uses technology as a cognitive tool*. All other categories were related to this core concept. The process employed to refine the description of how students experienced the learning environment that uses technology in the form of an expert system shell to facilitate higher-order thinking made use of several overlapping steps. These involved an explication of the story line, in which a general description of how the students experienced the learning environment is outlined. Evans (2007, p. 202) proposes that it is while explicating the story line that the researcher develops a story that "brings together the majority" of the elements uncovered during the research. Ideally only one core category should emerge.

A relationship between categories at a dimensional level as well as the way in which the categories relate to the core category was then outlined. Evans (2007, p. 202) suggests that this step involve "asking questions and making comparisons" of and between the categories and codes uncovered.

The relationships between categories were validated against the data by extracting salient quotations from transcripts of the focus group interviews held with the student group and incorporating them in a descriptive passage.

The quotations extracted from the focus groups interviews held with the student group are presented according to the following example:

FG 1.4.5:

Like we learn what our managers out there in the business world expect from us.

The numbering of the quotation can be decoded as follows:

- FG 1 indicates that the quotation is from the first focus group interview.
- 4 indicates that it was the fourth respondent who spoke during that interview.
- 5 indicates that it was the fifth individual quotation in that focus group's transcript.

The previously mentioned steps were not seen as distinct from one another but together allowed for the development of an analytic story. This analytic story was outlined in a descriptive passage (see Table 4.11).

3.7 Trustworthiness of the research findings and analysis

In conventional positivist research, quality is assessed by using validity, reliability and objectivity as criteria (Zhang & Wildemuth 2009, p. 6). Due to its interpretative nature the validity of "qualitative content analysis" cannot be assessed using the same set of criteria (ibid.). Creswell and Miller (2000, p. 126) indicate that the "validity procedures reflected" in constructivist thinking "present criteria with labels distinct from quantitative approaches such as trustworthiness" (ibid.). Gasson (2004, p. 89) points out that trustworthiness in qualitative research revolves around Lincoln and Guba's ideas concerning dependability, confirmability, transferability and credibility. The trustworthiness of this study will now be discussed with reference to its dependability, confirmability, transferability and credibility.

3.7.1 Dependability

Gasson (2004, p. 94) proposes that clear and repeatable procedures concerning the manner in which we conduct the research be required to ensure the dependability of findings. She suggests that "making explicit the process through which findings are derived is a useful way of ensuring their dependability”. This is supported by Zhang and Wildemuth (2009, p. 7) who indicate that to establish dependability the "consistency of the study processes" needs to be demonstrated. The following guidelines are proposed by Gasson (2004, p. 94) in order to establish dependability:

- Procedures employed to collect and analyse data should be defined.
- The ends that these procedures achieve should be articulated.
- Record these procedures so that others will be able to understand them.

An in-depth description of all methods used to collect and analyse data is provided to allow for the "integrity of research results to be scrutinised” (Shenton 2004, p. 73).

3.7.2 Confirmability

Confirmability is ascertained by examining the "internal coherence of the research product", which is made up of "the data, the findings, the interpretations, and the recommendations" (Zhang & Wildemuth 2009, p. 7). Gasson (2004, p. 93) proposes that distortions regarding confirmability be minimised by the researcher making explicit assumptions and frameworks regarding research findings. A theoretical framework together with a discussion and literature reflection (see 4.5) was conducted in order to make explicit the assumptions and frameworks applicable to the research findings.

3.7.3 Transferability

Transferability involves the degree to "which the researcher's working hypothesis can be applied to another context" (Zhang & Wildemuth 2009, p. 6). Gasson (2004, p. 97) indicates that the constant comparison method of data analysis can go some way toward establishing transferability and credibility. Findings were constantly compared to one another during the analysis stage of the study in order to establish categories and themes. Background information together with a theoretical framework on which the study was based was also provided in order to improve transferability to other contexts.

3.7.4 Credibility

Credibility concerns the assurance that the study "measures or tests what is actually intended" (Shenton 2004, p. 64). The following "provisions" are proposed by Shenton (ibid.) in order to promote confidence that the researcher has "accurately recorded the phenomena under scrutiny":

- using well established research methods
- random sampling
- techniques to encourage honest responses from participants (encouraged to be frank, opportunity for refusal, involve only those genuinely willing to take part, establish a report, right to withdraw at any time without disclosing a reason)
- "frequent debriefing sessions"
- "peer scrutiny of research project"
- reflective commentary by the researcher
- "member checks"
- thick "descriptions of the phenomenon under scrutiny"
- examining previous research findings.

Wimmer and Dominick (2006, p. 120) point out that leaving an "audit trail" would "help build credibility". An audit trail is a "permanent record of the original data used for analysis and the researcher's comments and analysis methods" (ibid.). By leaving and audit trail, others will be able to evaluate the researcher's thought processes and, in so doing, assess the accuracy of conclusions reached (ibid.).

In order to ensure credibility this study employed well-established research methods that the literature suggested were suited to research into computer technology-assisted learning interventions. Though purposive sampling was used to select the lecturers and instructional designers that made up the design team, random sampling was used to select focus group participants from the student population. To encourage honest responses from participants from both the design team and student sample focus group interviews, the following techniques were employed:

- A suitable rapport was established between all participants and the researcher who acted as facilitator during the focus group interviews.
- All participants were encouraged to be frank and forthright during focus group discussions.
- All participants were given the opportunity to refuse to participate at any time during the study.
- All participants were given the opportunity to withdraw from the study at any time during the study without any repercussions to themselves and without giving reasons for doing so.

Debriefing sessions, outlining themes and ideas that emerged from previous meetings, were conducted at the beginning of each meeting with the design team. Members were invited to comment on these to ensure accuracy. During the data analysis phase of the research the researcher constantly undertook a process of reflective commentary in the form of memoranda (see Addendum A). The researcher constantly reflected on the literature during the analysis phase of the research to identify parallels and to facilitate the accurate interpretation of findings.

Before a description of any of the conjectures and principles relating to the learning environment is presented, the data collection and analysis methods are outlined. In an attempt to leave a thorough audit trail, all tables on which the descriptions of the conjectures and principles are based are included when research findings are discussed.

3.8 Ethical considerations

The ethical considerations applicable to this study involved informed consent, voluntary participation and the avoidance of harm.

3.8.1 Informed consent

Informed consent is a consistent and indispensable aspect of qualitative research and involves providing participants with "accurate and complete information" that would allow participants to gain a complete understanding of the study (De Vos *et al*. 2009, p. 59). As a consequence of this information they should be in a position to make a "voluntary, thoroughly reasoned decision" concerning possible participation (ibid.). Information regarding this study was provided to the design team as well as to the student sample. A research participation information sheet was prepared and made available to the student sample (see Addendum B) as well as to the design team (see Addendum C). It was made clear to all participants that they were free to ask any questions and they were asked to complete a checklist that had been designed to ensure that they completely understood the nature of their involvement in the study (see Addendum D).

3.8.2 Voluntary participation

Participants from both the student population as well as those that made up the design team were made aware that their participation in the research was completely voluntary and that they could withdraw from the study at any time without having to provide reasons. They were assured that their withdrawal from the study would have no consequences.

3.8.3 Avoidance of harm

Avoidance of harm involves taking steps to ensure that participants are not "harmed in a physical and/or emotional manner" (De Vos *et al*. 2009, p. 58). This study did not involve any harmful physical activity or emotionally hazardous conduct.

Chapter 4

Data analysis and findings

Conjectures an principles associated with using computer technology as a cognitive tool to facilitate higher-order thinking (HOT)

4.1 Introduction

This study is concerned with two broad factors related to a learning environment that employs computer technology as a cognitive tool in the form of an expert system shell in order to facilitate higher-order thinking in foundation English communication students at TUT. The first is the formulation of design principles in the form of conjectures and principles with regard to this environment; the second outlines how students experienced working within the environment. This chapter presents the findings related to the first of these factors.

A review of the literature has indicated that to use technology as a cognitive tool, rather than merely to deliver instruction, is an effectual way to engage students in a deeper level of thinking. To design and develop an expert system requires students to contemplate a subject domain critically and encourages them to explore the domain at a more profound level.

A tentative or prototype design of the learning environment, based on a review of the literature as well as the creativity of the researcher, was presented to the design team. This environment evolved through a cyclic process of improvement and refinement. The design team was asked to work through many of the activities included in the tentative learning environment.

4.2 Overview of the contact sessions held with the design team

A design team comprising experienced English Communications lecturers and instructional designers was assembled on ten different occasions and a focus group interview was held after each of the design sessions. During these focus group interviews the design team was asked to comment on the activities and make suggestions for improvement. The interviews were transcribed and a preliminary or formative grounded theory analysis was undertaken after each of the focus group interviews. The discoveries made during this analysis were used to make modifications and adjustments to the evolving learning environment. These modifications were undertaken until it was generally agreed that the environment did not require further significant amendment. Table 4.1 provides a brief overview of these sessions as well as the substantive themes that emerged from a provisional analysis of transcripts of focus group interviews held after each of the ten contact sessions.

Table 4.1 An overview of the sessions held with the design team

Date of session	**Discussion / Programme**	**Substantive themes**
20 January 2011	• Introduction to the design process	• No substantive themes emerged; only initial impressions of the research undertaking were obtained.
2 February 2011	• Presented the tentative design to the design team. • This included: ○ Demonstration of a functional expert system. ○ Algorithmic representation of the expert system. ○ Handout of step by step guide to developing an expert system. ○ Paper-based exercises.	• The students should find the hands-on (active learning) experience enjoyable. • Those without programming or IT experience are likely to struggle, especially with programming logic. ○ Students may find the fact that they are going to 'program' something to be a daunting prospect. • Time is a real concern because of the initial steep learning curve (Learning what an expert system is and how to use the expert system shell). • It emerged that the tutorial presented to the design team was deficient in the following respects: ○ Cannot stand alone. ○ Language must be accessible to the students. ○ Terms need to be defined in a simple way. ○ Including more graphics may be useful. ○ Some students may move too far ahead or lag behind when working through the paper-based exercises and tutorials. ○ The paper-based exercises and tutorials could become too large and cumbersome if they are too detailed (terms defined, examples explained, etc.). • The paper based exercises and tutorial could be beneficial in the following ways: ○ They can serve as a good reference for later that could jog the students' memory.

Table 4.1 An overview of the sessions held with the design team (continued)

Date of session	Discussion/Programme	Substantive themes
		○ They could serve as a useful supplement to other training methods such as face to face facilitation. • Things that can be done to master using the software and become familiar with expert system logic: ○ Face to face demonstration of examples using a data projector. ○ Screen capture (Camtasia or Wink) with logical breaks. ○ Simple hands-on examples that progress from simple to complex. ▪ Progress from well structured to ill structured. • It was conjectured that the bulk of learning would take place while drafting the flow-diagram. ○ Software will serve as an assessor. ○ It may be effective to supplement laboratory sessions with conventional class time. This may lighten the load on laboratory resources.
4 February 2011	• Refinement of learning environment, based on suggestions from last design session presented to the design team.	• Working from paper-based exercises and design activities to hands-on development using the expert system shell was helpful. • It is important to allow students to work on their own at measured intervals. • Must start simply. • Were intimidated after the last session, felt better later. • Lecture broken into bits was helpful (paper-based, work on own, demonstration). • Screen-capture demonstration of how to develop an expert system was useful and could serve as a reference for later. • Stopping at logical points to make students work on their own would be useful. This could be seen as a way of decreasing scaffolding provided to the students. • It is important to break the presentation of information and demonstration into logical steps. • Helpful to train some students ahead of time to help other students (as assistants). • Face to face facilitation is important (ask question and get immediate feedback). • Screen capture demonstration of expert system development with logical interactive breaks was effective. • A trial and error approach is good for learning but a balance must be found in order to avoid counter-productive frustration. • Students must attempt activities on their own for a while before the facilitator shows them how it is done (This may be an effective way to gain foundational knowledge of software). • Need to make sure that the terms used are accessible to a novice (good to have novices as part of the development team). • Good idea to pilot intervention using a small group of students.
9 February 2011	• Refinement of learning environment, based on suggestions from last design session, presented to the design team. • Exploration of Communications subject domain was	• Paper-based exercises and tutorials (handouts) are a good idea. • Terminology needs more clarification (they need a clearer understanding of the concepts). • Good idea to explore the students' understanding of concepts before starting with exercises. • Provide examples to explain terms (as a starting point). • Equal participation in groups is a concern (some may not participate but then still be required to present models of

Table 4.1 An overview of the sessions held with the design team (continued)

Date of session	Discussion/Programme	Substantive themes
	included in this session.	understanding). • This may be less of a problem if groups are small (2 to 3) Scenarios depicting authentic or realistic situations may be useful when used as examples. • They must understand that they are creating something new. • Constant or well-placed revision of terms used in the development of an expert system would be useful. • Thought must be given to how groups are constructed (composed). • People must not be forced to work in groups all the time. • It may be helpful to brainstorm different communication contexts and then get feedback. • Role-play may be useful.
16 February 2011	• Refinement of learning environment that included the exploration of the subject domain, based on suggestions from last design session, presented to the design team.	• Face to face interaction is useful. • Subtle guiding of discussions is useful. • Take a step back and summarise (synthesise) learning points that may have emerged during discussions. • A reduction from specifics to an understanding of concepts. • Breaking lecture into manageable chunks was useful, segmentation. • Could use different clips to discuss each section/concept. • It is useful to go back to video clips of scenarios to discuss and allow learning points to emerge. • Presenting 'real-life' situations to students worked well. • Big classes may present challenges. • Could be overcome by using groups and getting feedback from groups. • Consolidate understanding by allowing students to come up with their own examples/scenarios (just one example) (link previous exercise with what was done today). • The progression from multiple choice test items to open-ended test items provided good scaffolding. • Visuals added interest and created a contextualised point of departure. • Face-to-face (ad hoc) demonstration of flow-charting generally worked well. • Immediacy of flow-charting worked well. • Might be a good idea to give students a choice of how to represent understanding (What about both?). • Flowchart creates a good representation of understanding (link between theory and practice). • Is flow-charting the best way to represent understanding practically? Needs exploration.

18 February 2011	• Refinement of learning environment that included the exploration of the subject domain, based on suggestions from last design session presented to the design team.
	• Making the link between conceptual understanding and a representation (externalisation) of that understanding was included in this session.
		• Good way to get to the logic of representing understanding using a flowchart.
		  ○ Students had to go through the thought process of getting to questions (help to understand).
		  ○ They were practising doing this without them knowing they were doing it.
		    ▪ Were not intimidated by vague/abstract questions.
		• Be careful about using humorous skits (dual signalling could confuse meaning).
		• It may be an idea to use natural language to represent expert system logic.
		• Facilitators need to be trained for constructivist interaction.
		  ○ Need to know what to do with a 'dead spot', must not revert back to lecturing.
		  ○ Constructivist teaching does not come

Table 4.1 An overview of the sessions held with the design team (continued)

		naturally.
		• Students need to be encouraged to overcome their natural resistance to speaking in groups (socio-constructivism, the need to speak to construct).
		• Video clips involved the students well and combined effectively with face to face facilitation.
		• Bridging the gap between conceptual understanding and the representation of that understanding worked well.
		  ○ Provided a natural progression from one step to another (Conceptual understanding to externalisation of that understanding).
		  ○ Students need not all think about what questions to ask (they are already there) (made gap more digestible).
		  ○ Also good that we were familiar with flow-charting shapes beforehand.
		• Basing learning in reality was good (video clips, newspapers).
		• Good to let them come up with their own questions (do not provide them with the questions).
		• May not be a good idea to ask where we should start (better to ask where they wanted to start from).
		• Learning is going to take place when they go back in their groups and work on their own.
		  ○ Negotiate solutions to problems among themselves.
		  ○ The facilitator will also learn much about how to facilitate this (would need to be responsive to what they come up with).

23 February 2011	• Refinement of learning environment that included the linking of conceptual understanding to a representation of that understanding, based on suggestions from last design session presented to the design team.
	• Group development exercise included in this session.
	• Exploration of ideas concerning the problem presentation.
		First focus group interview (After getting group to come up and develop expert system with reference to the previous sessions exercise and consolidated questions).
		
		• Developing the expert system will test the validity of the logic.
		  ○ The functional expert system would be like a template or guide to assessing the correctness of the logic, etc.
		• Development of a functional expert system in a large group is helpful.
		• Students must have hands-on involvement; looking is helpful but not as good as doing.
		• How to group the students is a concern (especially for large classes).
		• How are we physically going to demonstrate the development (overhead projector, NetOpp, etc.)?
		• They must transfer their understanding to the computer.
		• Important to develop as part of the overall demonstration.
		• The development of a functional expert system will also give the facilitator the opportunity to assess actual understanding (see where the problems may be).
		
		Second focus group interview (brainstorm the nature of the ill structured problem that will be presented to the students).
		
		• Ill structured problem should be based on a real-life scenario.
		• This problem should be presented in the form of a written paragraph.
		• Could use video clips again to present ill structured problem.
		  ○ Could constantly refer to video for more info.
		  ○ Put in writing to support information presented in video.

Table 4.1 An overview of the sessions held with the design team (continued)

		• All suitable domain content should be present in the video clips.
		• The functional expert system could indicate how communication could have been more effective.
		• Important to brainstorm first to find solution (How can we get an expert system out of this?).
		• Facilitator must be in the background.
		    o Answer a question with a question to guide students toward a solution (must not be directive).
		    o Must make sure that all elements are being covered.
		    o Could be like a resource of information
		• All learning points (domain content) must be implied in the ill structured problem.
		    o Must make sure that students detect these.
		• After a period of development one needs to assess to make sure that domain has been covered properly.
		• Define roles in each group.
		• Breakaway groups offer a solution to group problem and collaborative efforts.
		    o Must go back to their groups to refine understanding.
		• Possibly get different groups to evaluate one another's functional expert system.
		    o Authentic way to assess.

25 February 2011	• The problem in the form of a conceptual brief was presented to the design team. • The development of a functional expert system began.	• Comprehensive outline of the problem is a useful reference. • Conceptual brief is an improvement on a conventional scenario. • Structure of problem presentation was effective, progress from a broad outline to a more specific articulation of the dilemma. • Thought needs to be given to when the facilitator should hand out the problem statement. • Starting the development at this stage was not daunting due to scaffolding, background, flowchart design. • Utility of the flowchart designs became apparent at this stage. • Preliminary development exercises made concentrating on externalisation of understanding easier. • Learning to use the expert system shell functionally was useful, less abstract. • Facilitator should be available during the development process to provide scaffolding. • Students must be encouraged or allowed to ask questions during development. • Students must be encouraged to reference the flowchart symbols during development.
2 March 2011	• Development of a functional expert system was continued.	• Development of the functional expert system revealed faulty logic in the flow-diagram design. • Making the shift from paper-based design to functional development using the expert system shell needs to be scaffolded. • Too much time must not elapse between learning how to develop and actually developing the expert system. • Students must be encouraged to involve themselves in the hands-on development. • The development facilitated an exploration of the logic of the subject domain. • Higher-order thinking will start properly when the students work on the inference part of the expert system.
4 March 2011	• Development of a functional expert system was	• Hands-on development has a positive influence on the depth of understanding.

Table 4.1 An overview of the sessions held with the design team (continued)

	continued. • Ideas regarding impact on learning were explored.	• Encourages logical thinking concerning the subject domain. • Flaws in flowchart design of the expert system are exposed through development. • Important to make sure the logic does lead to an inference and not an aggregation of options. • Expert system development encourages students to reflect on learning. Turns information into knowledge. • Development of expert system allowed for a more comprehensive exploration of the domain. • Highlighted the fact that there are different or individual levels of understanding.

4.3 Describing the learning environment

What follows is a description of the learning environment that was devised by the design team during the design phase of the research. The following seven broad sections were identified:

- Students' initial exposure to the learning environment.
- Presenting the ill structured problem.
- Explicating the expert system concept.
- Demonstrating a functional expert system.
- Explaining flow-diagram representation.
- Exploring the subject domain using a flow-diagram.
- Modelling understanding by exploring the ill structured problem.

Before this description is presented it is necessary to set the scene by providing background information concerning the subject domain as well as the context that the learning environment forms part of.

4.3.1 Setting the scene

The subject English Communications Skills is offered to first year foundation students in the Information Communication Technology (ICT) department and is designed to allow students to gain communicative competence in a technical or corporate environment. The subject aims at enabling students to gain an understanding of how to evaluate any communication situation in order to participate effectively within it. Students are encouraged to consider carefully the following aspects of a communication situation in this regard:

- Context (the surrounding situation in which the communication takes place).
- Message (the actual content of the communication).
- Audience (the people who receive the message).
- Purpose (the reaction expected from the audience).
- Product (the physical form the communication takes).

These aspects of a communication situation are integrated in a model that is referred to by the acronym CMAPP (pronounced C map). The CMAPP model, or any similar variant of it, is considered the subject domain of the learning environment.

The English Communications Skills subject is offered over a single semester, with two one and a half hour contact sessions a week. One of these weekly sessions is presented in a computer laboratory while the other is conducted in a standard lecture environment.

A literature review has indicated that it would be appropriate for the students to represent or model their understanding of the domain by creating a functional expert system in order to promote a higher level of thinking. The learning environment described in paragraphs 4.3.2 to 4.3.8 is designed to guide students toward the process of developing an expert system that models an understanding of the subject domain. The description of the environment is presented in the form of recommendations, suggestions and examples of exercises and questions aimed at guiding the facilitator.

4.3.2 Initial exposure to the learning environment

During the students' initial exposure to the learning environment, the facilitator should initiate discussion concerning the various challenges to effective communication and possible solutions to these challenges. The students should then be made aware of the usefulness or function of an expert system and also acquire insight into the components of an expert system.

It is advisable to show the students various video clips depicting communication taking place in differing contexts. These video clips should involve difficult or challenging situations in which communication between the parties involved is not conducted satisfactorily. Once the students have viewed these video clips the facilitator could obtain feedback from them and initiate a discussion by posing probing questions. The following questions may be effective in this regard:

- What went wrong in each of the clips?
- What could have been done better?
- What advice could have been given to the communicators in the video clips?
- Do you think that they need help in order to communicate better?
- What sort of help could be suggested?

4.3.3 Presenting the ill structured problem

Once the students have been sensitised to the challenges that may be present in a communication situation, it would be appropriate to make them aware of the ill structured problem that they will be required to explore during the design and development of the expert system. It is advisable for the facilitator to guide the students toward an understanding of the problem and outline the process that might need to be followed in order to develop a functional expert system that may provide a solution to the problem.

On a face to face basis the facilitator should go through the process that needs to be followed in order to develop an expert system. This process can be outlined as follows:

- Become familiar with the definition of an expert system.
- Become familiar with the ways in which the logic of an expert system can be represented, i.e.
    - Flow-diagram
    - Pseudo code (natural language).
- Become familiar with how to use CourseLab as an expert system shell.
- Become familiar with the expertise of the human expert that the system will mimic (Domain knowledge, CMAPP).
- Work in groups to develop the expert system.

4.3.4 Explicating the expert system concept

When explaining what an expert system is, it is important that the facilitator provide the students with an accessible definition of an expert system and sketch its components. Students must also be made aware of the discrete roles that individuals may play when constructing an expert system.

The following is a definition and an outline of these components and roles:

- An expert system can be defined as a computer program that mimics or imitates the reasoning of a human expert.
- An expert system is typically comprised of:
    - A knowledge base.
        - This knowledge base consists of facts and the rules that can be applied to those facts in order to solve problems.

    - A user interface that enables information to be obtained from the novice user and which enables a solution or suggestion to be communicated to the user.
    - An Inference engine that takes the user's input and makes suggestions with reference to the knowledge base.
- Roles of the people involved in an expert system's construction and use:
    - Domain expert
    - Knowledge engineer
    - User

4.3.5 Demonstrating a functional expert system

Once the students have gained some insight into what an expert system is and what process needs to be followed in order to design and create one, the facilitator should demonstrate a functional expert system to the students using a data projector. This expert system should not be excessively complex or abstract and should be in a domain that the students are likely to be familiar with. An example of an expert system that could serve this purpose would be one that helps a novice identify a suitable type of dog. This expert system could ask the user questions regarding the dog's size, coat length, maintenance and temperament and then recommend a type of dog that meets the criteria that the user has selected. It is useful to provide students with a handout that contains an algorithmic flow-diagram that outlines the logic of the expert system (see Addendum E). The facilitator should guide the students through the logic of each series of options using both the handout and the demonstration. The demonstration could also be supported by a paper-based step by step guide that outlines the development process using the applicable expert system shell (see Addendum I) as well as a handout that indicates common errors made while using the software (see Addendum J).

4.3.6 Explaining flow-diagram representation

The facilitator should explain to the students how to represent the logic of an expert system using a flow-diagram. They should be provided with a handout that could serve as a reference to the flow-diagram symbols (Addendum H). Students should be provided with exercises that would allow them to become familiar with representing a decision-making process in the form of a flow-diagram. It may be useful to provide them with a simple example of a decision structure both in the form of an IF THEN statement and in the form of a flow-diagram. Figure 4.1 illustrates what may be a useful example:

A flow-diagram that outlines the logic used to decide what music is most appropriate for a particular function could look like the one in figure 4.1.

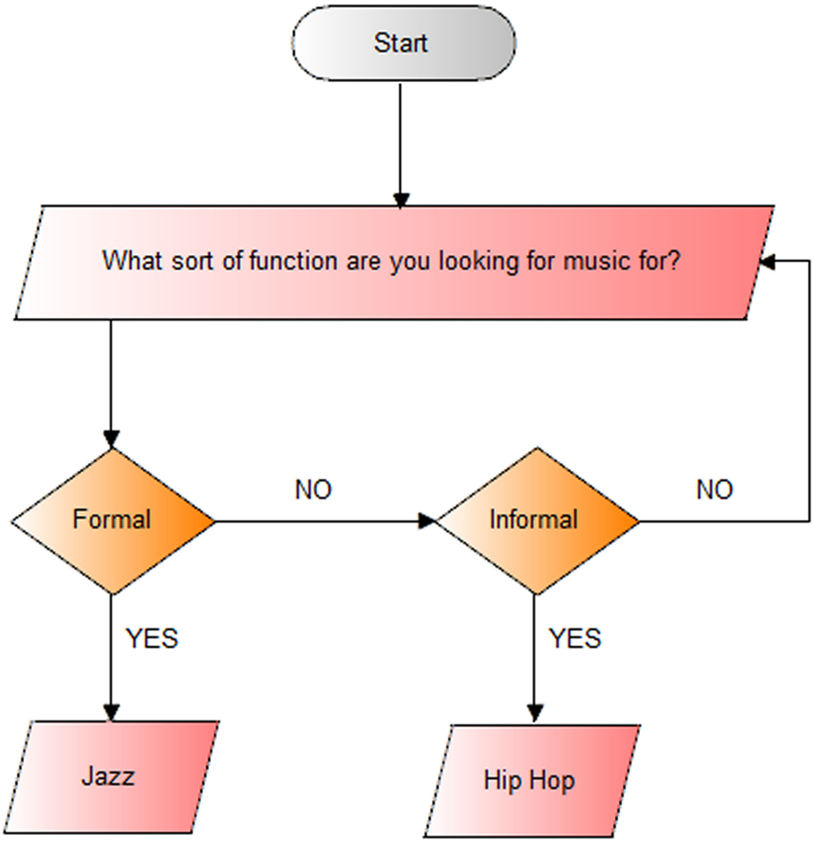

Figure 4.1 An example of a simple decision structure

The same sort of decision structure used in Figure 4.1 could be expressed in the form of a simple IF THEN statement such as the following:

IF Formal THEN

Jazz is appropriate

IF Informal THEN

Hip Hop is appropriate

Students should then be asked to convert IF THEN statements into flow-diagrams and flow-diagrams into IF THEN statements. The following may be a useful example:

Represent the following IF THEN statement using a flow-diagram such as the one in Figure 4.1:

IF the object has four corners THEN

It is a square

IF the object is round THEN

It is a circle

Students could also be asked to complete more complex algorithmic flow-diagrams that represent a series of IF THEN statements. The following may be a helpful example:

Complete the flow-diagram in Figure 4.2 representing the following IF THEN statement:

IF the candidate has a matriculation certificate THEN

IF the candidate has experience THEN

Send an invitation letter for an interview

IF the candidate has no experience THEN

Send a letter declining application

IF candidate has a degree THEN

Send an invitation letter for an interview

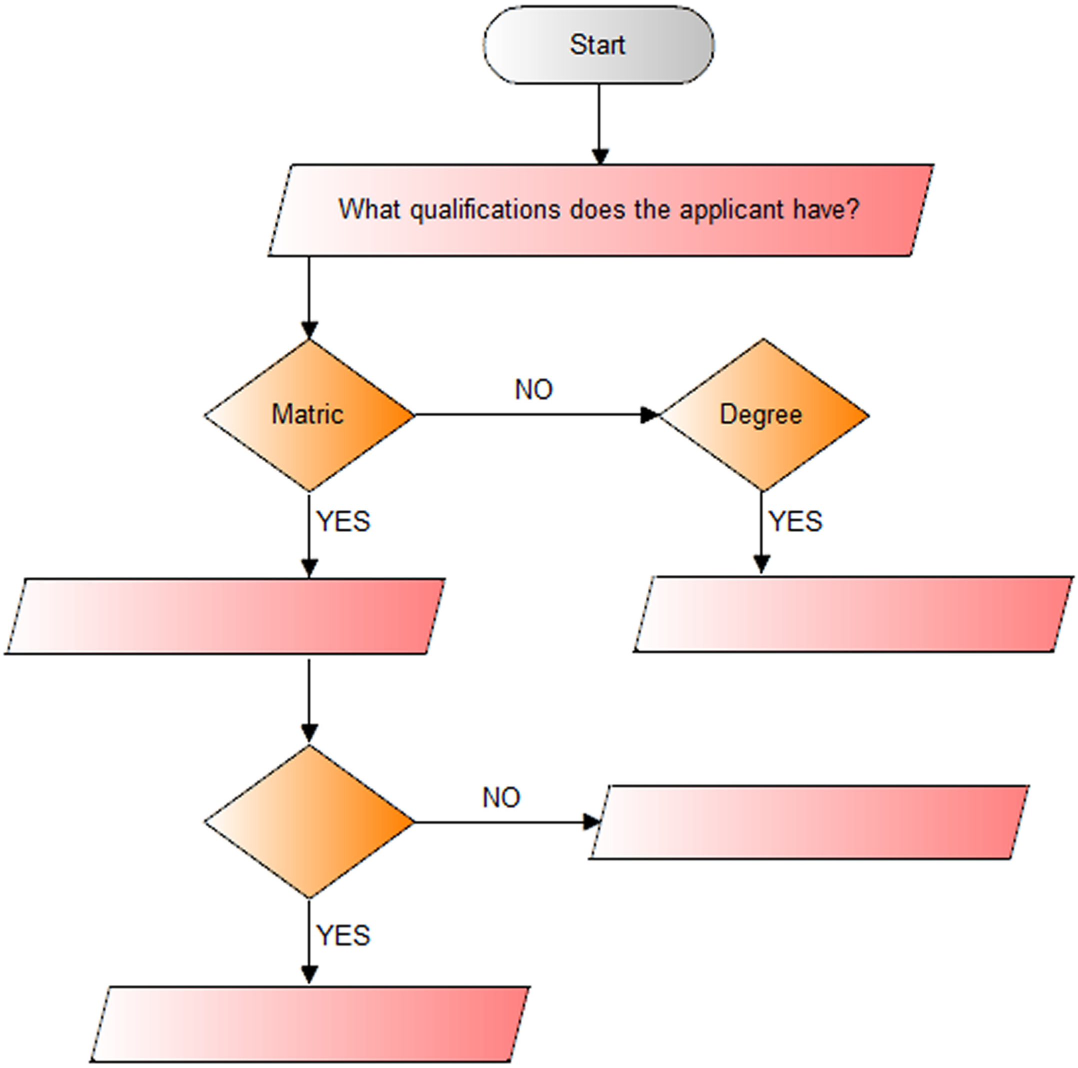

Figure 4.2 A flow-diagram representing an invitation to a job interview decision structure

It may be useful to ask the students to think of a simple real world problem that would need to be solved by selecting a series of options similar to the preceding examples. This could then be represented in the form of a series of IF THEN statements as well as by using an algorithmic flow-diagram.

The facilitator should guide the students through the development of one or more of the preceding algorithmic formulations using CourseLab as an expert system shell.

4.3.7 Exploring the subject domain using an algorithmic flow-diagram

In order to situate the learning within an authentic setting as well to create a context that students can relate to, students could be shown video clips that depict various forms of communication taking place. These video clips could serve as a reference for the students and would allow for the learning to be situated within a realistic setting that the students may be able to relate to. Once the first set of video clips has been shown to the student group, a brainstorming session should be held with them in order to explore their understanding of the domain knowledge. The following probing questions could be put to the students in order to facilitate this process:

- What does the term ‘context’ mean to you?
- How can the physical setting influence the communication process?
- What possible relationships could there be among the people and how could these influence the communication?
- How can interference influence the communication process?
- What other factors make up the context of the communication?

Once this brainstorming exercise has been completed, the student group could be divided into three groups; two of the groups could be asked to wait outside the venue while the remaining group is shown a different video clip depicting a communication situation (some form of communication taking place). This group should be told that the other groups are going to be asked to pose questions in order to determine a certain aspect of the communication that was depicted in the video clip. They must answer these questions as simply as possible and must be careful not to volunteer information. The other groups should then be called back to the venue to ask these questions. The facilitator should record all the questions as well as the answers to the questions on a whiteboard or could use a data projection of a word processing application. The facilitator must not sensor the questions and answers but must ensure that the questions are rational and are not excessively open-ended. For example, students must not be allowed to ask directly what the context in the communication depicted in the video clip was. They must ask probing questions to determine this context. This process should be repeated until all the groups have had an opportunity to view a video clip and answer questions. Once this process has been completed and all the groups are present in the venue the facilitator should consolidate the questions, allowing the student group to guide the process. The students should be asked to decide which of the questions have been repeated and which of them really explore or probe the communication situation appropriately. A repeated or irrelevant question should be discarded, leaving only questions that are considered by the group to be pertinent. The facilitator must record the consolidated questions separately and specify (indicate, separate, record) the separate (discrete) answers to these questions. The facilitator could also ask the student group what other possible answers could there be if the situations were different. These answers could be consolidated and made more abstract. The questions and answers could then be represented or rendered using a flow-diagram. This representation should then be projected onto a screen using a data projector or a whiteboard.

4.3.8 Modelling understanding by exploring the ill structured problem

Once the students have been guided through the process of examining a communication situation by posing appropriate questions and then representing these questions using an algorithmic flow-diagram, they should be given the task to design and develop a functional expert system. The facilitator should go through the ill structured problem again with the students, making sure that they clearly understand what they are required to do. The students should collaborate in groups of three during the development process. At the end of each development session the groups of three will temporarily merge with a larger group of nine to compare and contrast ideas. They will be required to answer the following questions:

- What were the differences between the way in which your group designed / developed the expert system and how the other groups did this?
- What did you learn from this?
- How are you going to use this in your design / development?

4.4 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?

Once the design of the learning environment was satisfactory a more comprehensive grounded theory analysis was conducted in order to discover and formulate design principles in the form of conjectures and principles. This analysis was also used to make minor modifications to the environment that was eventually presented to the foundation students.

In order to gain an in-depth understanding of the conjectures and principles involved in the design of a learning environment that uses computer technology in the form of an expert system shell, a grounded theory approach was adopted. The data analysis was designed to provide extensive insight into the following research question:

- 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?

The conjectures and principles formulated through a grounded theory analysis of transcripts of focus group interviews held with the design team are presented next. These conjectures and principles are initially presented in a table that lists their respective characteristics, procedures and arguments. This table will be used as the basis for a description of these conjectures and principles.

To gain an understanding of how these conjectures and principles were arrived at, a brief outline of how they were formulated is initially presented.

4.4.1 Design principles in the form of conjectures and principles

To arrive at the conjectures and principles, transcripts of all the focus group interviews (see Addendum F) conducted with the design team after each of the ten development sessions were coded using the application Atlas.ti. These codes were grouped into categories and arranged in a table that has the following headings:

- Category
- Codes
- Quote to support creation of the category
- Comments

Table 4.2 presents a portion of the table (see Addendum A for the full table) used to sort codes into categories. The quotations helped to keep the analysis grounded in the data and the 'comments' or memoing assisted with the formulation of design principles in the form of conjectures and principles.

Table 4.2 A portion of the table used in the category creation process

Category	**Codes**	**Quote to support creation of category (Groundedness)**	**Comment**
Facilitation Lecturer-student	Face to face facilitation	"I think you should also consider having it facilitated face to face other than working off a printed	The initial handouts may have been confusing or too advanced and difficult to

Table 4.2 A portion of the table used in the category creation process (continued)

Category	Codes	Quote to support creation of category (Groundedness)	Comment
interaction.	Face to face facilitation (continued)	sheet. Because what happens then, is if you do step by step and they have to follow you step by step as soon as there is an issue then you can actually go and address a specific question that they've got." "You might give this to them as a reference for later on. But the first time they encounter that you actually facilitate a simple example but on a face to face basis." "… a group of logistics students might struggle to grasp the concept of programming logic, but I think just to support them, give a hand-out but also maybe go through it step by step in class as well. To pre-empt any problems that they might have." "If you are going use paper, you are going end up with quite a hefty manual if you have to predefine everything and give the examples. Even if you explain to them what a variable is, it's still not going to make sense until they see an example."	follow. There were too many gaps that needed to be filled in through face to face facilitation. Examples needed to be worked through during contact sessions, facilitated by the lecturer on a face to face basis. The step by step guide could serve more as a reference then an initial exposure to the expert system shell. Face to face facilitation would be particularly important for students who have not had exposure to programming. There are too many unforeseen issues / problems / occurrences that the students may encounter to anticipate them all in a paper-based tutorial. Face to face facilitation allows you to address these on the fly.
	Step-by-step guide	"I think just to support them, give a hand-out but also maybe go through it step by step in class as well. To pre-empt any problems that they might have." "If you regard that this will be the tool to design the expert system in the end it shouldn't be an obstacle. They should have a hand-out for reference later on. You explain and then in their own time they can come back and look it up again." " Might help when … you know if they do forget then they've got an assignment and they've got to go and refresh and … what the students do is, they sit in class and they nod seemingly intelligently and	The sense here is that the step by step guide should serve as a reference for later and should be supported by face to face demonstrations of examples. If they are going to learn to use the software then they will need an understanding of the steps involved to be able to use it appropriately.

Table 4.2 A portion of the table used in the category creation process (continued)

		understanding, but they don't really, so if you can give them something that they can kind of play with later on."	

In order to allow for the formulation of conjectures and principles that are based on these codes and categories a table was designed using Van den Akker's (quoted in Plomp 2007, p. 20) suggestion for the formulation of design principles as a guide:

> *If you want to design intervention X [for the purpose/function Y in 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.*

The table, based on Van den Akker's guide, has the following headings:

- Category/code
- Characteristics (substantive emphasis)
- Procedures (procedural emphasis)
- Arguments

Each category was listed in this table where appropriate characteristics, procedures and arguments were determined in accordance with Van den Akker's (Plomp 2007, p. 20) guidelines. Through a process of constant comparison, these categories were then reorganised under the following headings:

- Initial exposure to the learning environment.
- Discovery learning.
- Designing the expert system.
- Creating subject (domain) awareness.

- Representing understanding (modelling).
- Development of a functional expert system.
- Students' engagement with the problem statement.

This reorganised table was used as the basis for the descriptions of the conjectures and principles associated with the learning environment. To enhance the credibility of the descriptions of the conjectures and principles formulated during this study, these tables (see tables 4.3 to 4.9) are included before each of the conjectures and principles is described.

4.4.1.1 Initial exposure to the learning environment

Table 4.3 lists the characteristics and procedures linked to the students' initial exposure to the learning environment as well as the arguments associated with these characteristics and procedures.

Table 4.3 Conjectures and principles related to the students initial exposure to the learning environment

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
Initial exposure to learning environment • Expert system shell • Simple example	It is advisable for the initial facilitation to be conducted primarily on a face to face basis. It is advisable that handouts that outline the development process support the face to face facilitation. It is advisable for this handout to include a step by step guide and terminology that is appropriate to the development environment. It is advisable for the facilitator to work through a simple example with the students in order to demonstrate the functionality of the expert system shell. It is advisable that the students undertake a practical exercise to consolidate their understanding of concepts explained to them.	The facilitator should work through a simple example that demonstrates the pertinent functionality of the expert system shell. This example should be presented to them on a step by step basis and should be designed to pre-empt any problems that the students may encounter when interacting with the development environment. The handouts should be designed and created in such a way that they support the face to face facilitation and can serve as a reference for the students when they work on their own.	A handout, that includes a step by step guide and terminology, would be particularly useful support for students who do not have a background in software development (or an understanding of programming logic, terminology, etc). This handout can be referred to in the students' own time. By designing the handouts to operate in harmony with the face to face facilitation, students can refer to the handouts while the facilitation is taking place. This will allow them to use the handouts to enhance the way they experience the learning session. A practical exercise could be given to the students to expose / uncover / reveal (make them more aware) of the gaps in their understanding. When students are made to demonstrate their understanding they often discover that they do not grasp the concepts as well as they may have thought they did. It may be difficult and impractical to anticipate all issues /concerns / problems / difficulties that the students may have and include them in a comprehensive handout or step by step guide. Working through examples on a face to face basis will allow the facilitator / lecturer to address these issues as they arise.

Table 4.3 Conjectures and principles related to the students initial exposure to the learning environment (continued)

			Examples will allow the students to make sense of the concepts. These examples will make the concepts less abstract and more tangible. As a consequence, the students may be in a better position to apply the learning. Learning to develop an expert system using CourseLab as a shell should not be an obstacle for the students. Sufficient material should be made available to the students so that they can learn to develop their expert systems easily (seamlessly, effortlessly). Students often do not realise that they do not understand a process / explanation / lesson demonstrated / given / conducted by a lecturer. A handout that outlines this process in a step by step manner will serve as a reminder or a reference that can be referred to when they get stuck.

Table 4.3 was used as the basis for the description of the design principles associated with the students' initial exposure to the learning environment that uses technology as a cognitive tool in the form of an expert system shell.

4.1.1.1.1 Description of the conjectures and principles related to the students' initial exposure to the learning environment

When students are first exposed to the learning environment it is advisable for the facilitator to interact with the students primarily on a face to face basis. The facilitator can do this by working through a simple example that demonstrates the pertinent functionality of the expert system shell to the students. This demonstration should consist of a step by step guide on how to develop the expert system demonstrated in the example and should be supported by a printed handout.

Learning to develop an expert system using CourseLab as an expert system shell should not be an obstacle for the students. Sufficient material should be made available to the students so that they can learn to develop their expert systems easily. By designing the handout to operate in harmony with the face to face facilitation, students can refer to the handout while the facilitation is taking place. This will allow them to use the handout to enhance how they experience the learning session. Students do not always realise that they do not fully follow or understand a process that has been explained to them on a face to face basis. A handout that outlines the process in a step by step manner will serve as a reminder or a reference that can be referred to when they get stuck.

It is also advisable to include terminology used in a basic software development environment in a handout, as this would allow students to refer to it when they need clarity concerning a particular issue. A reference of this nature would be particularly useful to students who have not had much exposure to a software development environment or an environment that requires any understanding of computer programming logic.

The face to face facilitation is an important part of the students' initial exposure to the learning environment as it is impractical to anticipate all concerns and difficulties that the students may have and to include them in a comprehensive step by step printed guide. The face to face interaction would allow the facilitator to address these concerns as soon as they arise. This is similar to "just in time knowledge delivery" proposed by Cole, Fischer and Saltzman (1997, p. 50) when they suggest that when a just in time strategy is employed "knowledge delivery takes place soon enough that it is applied to the appropriate situation, and late enough that the user does not have to go through training or information overload" (ibid).

The use of examples will make the concepts to be mastered less abstract and more tangible. As a consequence the students may be in a better position to apply the learning. Once the facilitator has worked through the example with the students, they should be allowed to undertake a practical development exercise in order to consolidate their understanding of the concepts demonstrated to them. This practical development exercise could consist of the development of a simple expert system that requires the user to make a selection from two possible alternatives. When students are made to demonstrate their understanding they often discover that they did not grasp the concepts as well as they might have thought they did.

4.4.1.2 Discovery learning

The learning environment conceived by the design team during the design stage, exhibited many of the characteristics of a discovery-learning environment. This environment required students to be supplied with foundational knowledge in manageable chunks before they were left to work independently to uncover information on their own. It was considered important that students be provided with various resources that they could draw on during the learning process and be given the freedom to request assistance at certain considered stages. Table 4.4 lists the characteristics, procedures and arguments related to the discovery learning characteristics of the learning environment formulated by the design team.

Table 4.4 Conjectures and principles related to characteristics of discovery learning

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
Discovery learning • Foundation knowledge • Providing support: ○ Screen capture ○ Worked examples ○ Paper- ○ based (step by step) • Manageable chunks • Hands-on • Work independently	The learning environment must guide the students toward acquiring foundational knowledge of concepts before encouraging them to discover information on their own. Foundational information should be presented to the students in manageable chunks. After each of these chunks students should be provided with a practical task to complete. It is advisable to allow students to apply their understanding once a particular concept has been explained to them. It is advisable to allow students to discover information on their own after they have acquired a certain level of foundational knowledge. It is advisable to encourage students to adopt a 'trial and error' approach to developing their expert systems. Students should only be left to discover information on their	Careful attention must be given to the sequence of instruction: • Provide students with foundational knowledge through: • Handouts • Step by step demonstrations of the development of simple worked examples • Explanation of flow-diagram symbols • Explanation of expert system concept and logic • Students should complete exercises that involve completing simple flow-diagrams (Algorithmic flow-diagrams that have very limited options and alternatives). • Students should design their own expert systems using flow-diagrams. Students should develop their expert systems using the expert system shell; the facilitator should be on hand to provide assistance when necessary.	The facilitator can use the feedback to determine whether the students have reached an irreconcilable impasse. Students will become demoralised if they are left to discover information on their own before they have acquired sufficient foundational knowledge. Breaking material into small chunks allows the student to assimilate material more effectively. A long, uninterrupted presentation may result in excessive cognitive load. The practical application of learning after each chunk of learning would reinforce the learning and reveal its relevance to the student. Presenting material using a 'screen freeze' (interactive screen capture demonstration) method may be an effective way of breaking it into manageable chunks. The demonstration 'freezes' at logical (salient) points during the development; students can interact with the demonstration and 'start' it again once they feel they are ready. Students could ask questions as soon as they encounter difficulties. This 'direct interaction' allows them to pose their question to the facilitator before they have forgotten the problem encountered. After each step (logical step) the students consolidate their understanding by applying

Table 4.4 Conjectures and principles related to characteristics of discovery learning (continued)

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	own for a limited period of time before the facilitator offers guidance. An interactive screen capture demonstration that guides the learners through the development of a worked example of an expert system could be used to familiarise them with the development environment as well as the expert system concept. This demonstration should be made available to the students as a resource that they can use to assist them while working in the discovery learning environment.	Scaffolding could be decreased by beginning with a step by step demonstration, then asking students to participate in the demonstration by suggesting succeeding steps in the development process and then finally developing an example of an expert system on their own. Facilitators should allow students to pose questions freely and provide them with timely feedback. The screen capture demonstration should be interactive and consist of written explanations of the development process. It is advisable to include a paper-based version of the screen capture demonstration. The problem presented to the students should initially be very simple and well structured. As the students progress the problem presented to them can become more ill structured. The facilitator could monitor the students' understanding and	something; this may assist in the creation of schemata in the long-term memory. In discovery learning students are encouraged to undertake activities that build on existing or foundational knowledge (Castronova, 2002:2). If the students are left to struggle on their own before they have acquired a fundamental understanding of concepts, they will not have a foundation on which to build new knowledge. They will not be able make linkages between existing knowledge and new knowledge. Active participation is an important characteristic of a discovery or constructivist learning environment. Discovery learning does not place significant importance on correct answers and considers failure as a constructive part of the learning process (Castronova 2002, p. 2). Discovery learning combined within guided learning strategies, where the facilitator establishes a balance between letting the students find their own way and guiding them toward a desired outcome. By being left to discover information on their own the students are likely to gain a deeper understanding of applicable concepts and learn extra information beyond that which is

Table 4.4 Conjectures and principles related to characteristics of discovery learning (continued)

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
		progress by obtaining feedback from the students and through observation. The screen capture should be broken into logical sections and the interactive properties of this demonstration would allow the students to proceed to the next section once they are familiar with the preceding one. Facilitators should not provide the students with solutions to problems or obstacles too readily. They should be left to struggle on their own and discover solutions to difficulties on their own. Facilitators should only step in once students become demoralised or once the impasse becomes irreconcilable.	being taught by the lecturer.

A description of the design principles associated with these discovery learning-related characteristics is presented next.

4.4.1.2.1 Foundational information

Before students are left to discover information on their own in a discovery learning environment, they should be provided with foundational information in manageable chunks. They may become demoralised if they are left to discover information on their own before they have gained at least a basic insight into the area of investigation. In discovery learning students are encouraged to undertake activities that build on existing or foundational knowledge (Castronova 2002, p. 2). If the students are left to struggle on their own before they have acquired a fundamental understanding of concepts, they will not have a foundation on which to build new knowledge. They will not be able make linkages between existing knowledge and new knowledge. The foundational information can be presented to the students using paper-based handouts, step by step demonstrations of the development process, paper-based explanations of flow-diagram symbols and explanations of the logic inherent to expert systems.

4.4.1.2.2 Manageable chunks

Breaking material into small chunks allows the student to assimilate material more effectively. A long, uninterrupted presentation by the lecturer or by means of a screen capture may result in excessive cognitive load. Students need to be encouraged to apply their understanding once a particular concept or process has been explained to them. This may be achieved by giving the students a practical exercise to complete at calculated intervals. These practical development exercises could consist of developing a simple user interface for an expert system and then developing a simple functional expert system. The practical application of learning after each chunk of learning would reinforce the learning and reveal its relevance to the student.

4.4.1.2.3 Struggle unaided

A trial and error approach should be adopted while undertaking the practical development exercises and students should be encouraged to view their ‘mistakes’ as part of the learning process. Discovery learning does not place significant importance on correct answers and in this type of environment failures can be viewed as constructive parts of the learning process (ibid). By being left to discover information on their own the students are likely to gain a deeper understanding of applicable concepts and learn extra information beyond that which is being taught by the lecturer. It is, however, important that students are left to struggle without assistance for a limited period of time only before the facilitator steps in to offer guidance. The facilitator needs to establish a balance between letting the students find their own way and guiding them toward a desired outcome. Students are likely to become despondent and demoralised if they reach an impasse that they are not able to overcome.

4.4.1.2.4 Interactive screen capture demonstration

An interactive screen capture demonstration that guides the learners through the development of a worked example of an expert system could be used to familiarise them with the development environment as well as the expert system concept. This demonstration should be made available to the students as a resource that they can use to assist them while working in the discovery learning environment. Presenting material using a 'screen freeze' (interactive screen capture demonstration) method may be an effective way of breaking concepts or a process into manageable chunks. The demonstration 'freezes' at logical or salient points during the development; students can interact with the demonstration and 'start' it again once they feel they are ready. The screen capture demonstration should also consist of written explanations of the development process. It is advisable to include a paper-based version of the screen capture demonstration. This may make it more comfortable or convenient for the students to follow development activities and to read explanations of the development process.

4.4.1.2.5 Receiving assistance

While students are working on their own in the learning environment the facilitator should allow the students to pose questions freely and should provide them with timely and appropriate feedback. This would allow students to ask questions as soon as they encounter difficulties. This 'direct interaction' allows them to pose their question to the facilitator before they have forgotten the problem or impasse that has been encountered. This, together with observation, would enable the facilitator to monitor the students' understanding of the concepts being explored. The facilitator must, however, not provide the students with solutions to problems or obstacles too readily. They should be left to struggle on their own and discover solutions to difficulties by themselves. Facilitators should only step in once students become demoralised or once the impasse becomes irreconcilable. The facilitator can use the feedback obtained from the students in the form of questions to help determine whether the students have reached an irreconcilable impasse.

4.4.1.2.6 Scaffolding

It is advisable for the facilitator to provide scaffolding for the students in the learning environment by beginning with a step by step demonstration, then asking students to participate in the demonstration by suggesting succeeding steps in the development process and finally by instructing them to develop an expert system on their own. The problem presented to the students should initially be very simple and well structured. As the students progress the problem can become more complex and ill structured.

4.4.1.3 Designing the expert system

Before students begin the actual development of a functional expert system it is essential that they be encouraged to undertake various activities aimed at designing the expert system. Table 4.5 lists the characteristics, procedures and arguments related to these design activities.

Table 4.5 Conjectures and principles related to the design phase of the learning environment

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
Design • Flow-diagram • Posing questions (formulating) • Group interaction	It is advisable to encourage students to design their expert systems first on paper using flow-diagrams. It is advisable that the facilitator encourages the students to formulate questions that explore the subject domain appropriately.	The (algorithmic) flow-diagram symbols should be explained and demonstrated to the students. Non-laboratory contact sessions should be used to allow students to design their expert systems on paper using these symbols. Worked examples that show appropriate questions that can be used in an expert system and that outline its logic should be formulated by the facilitator. These examples should be as straightforward as possible. They could include incomplete flow-diagrams outlining the logic of a simple expert system.	Plotting the expert system on paper reduces the cognitive load because once you are familiar with the flow-diagram symbols, one can concentrate on the logic of the expert system and not on how to use the development software (expert system shell)

A description of the design principles associated with the design component of the learning environment is presented next.

4.4.1.3.1 Planning the expert system using a flow-diagram

When designing the expert system that models understanding of Communications concepts, students should be encouraged initially to plot the logic of the expert system on paper in the form of a flow-diagram. The (algorithmic) flow-diagram symbols should be explained and demonstrated to the students and non-laboratory contact sessions should be used to allow students to design their expert systems on paper using these symbols. Plotting the expert system in the form of a flowchart on paper reduces the cognitive load because once the students are familiar with the flow-diagram symbols they can concentrate on the logic of the expert system and not on how to use the development software (expert system shell).

4.4.1.3.2 Formulation of questions

It is also important for students to be encouraged to formulate questions that explore the subject domain appropriately. Worked examples that demonstrate appropriate questions that can be used in an expert system should be prepared by the facilitator. These worked examples must also outline the logic of an expert system and should be as straightforward as possible. Exercises that include incomplete flow-diagrams outlining the logic of a simple expert system could be used to support the examples that demonstrate the logic of an expert system.

4.4.1.4 Creating subject (domain) awareness

Providing students with suitable insight into the domain that is to be explored in the learning environment is an important part of the learning environment formulated by the design team. Table 4.6 lists the characteristics, procedures and arguments associated with creating domain awareness.

Table 4.6 Conjectures and principles associated with domain awareness

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments

Subject (domain) awareness
• Explore students' existing knowledge
• Scaffolding:
  ○ Examples
  ○ Immediate feedback
• Paper-based exercises:
  ○ M/C
  ○ Open-ended
• Video clips:
  ○ Realistic
  ○ Situate learning
	It is advisable to place the learning within a suitable context by exploring the students' understanding of various Communications concepts (domain). Facilitators should avoid offering explanations of Communications concepts without exploring the students' existing or current understanding.
	
	It is advisable to provide students with paper-based exercises to complete.
	
	Facilitators should avoid assumptions concerning the students' understanding of various terms used in the domain. Paper-based exercises that require a familiarity of domain-specific terms should be supported by activities that provide students with explanations of these terms.
	
	It is advisable to use examples to clarify concepts.
	
	It is advisable that during the orientation phase the facilitator be on hand to provide immediate face to face feedback
		It is advisable to conduct brainstorming sessions with the student group. This can be done by asking questions to probe for understanding and to initiate group discussion.
		
		The discussions that are initiated by the brainstorming sessions should incorporate explanations of terms used in the domain.
		
		Paper-based exercises should be formulated that are designed to explore students' understanding and that facilitate discovery learning.
		
		Facilitators should prepare examples of Communications situations that would make various Communications concepts less abstract.
		
		The facilitator should make the students aware that, even though they need to explore their own understanding and discover information for themselves,
			By conducting brainstorming sessions the facilitator can gage the students' current level of understanding and gain an understanding of where to pitch explanations. These brainstorming activities will also help to make students aware of communication concepts and serve to orientate students within the learning environment. Students become confused and disorientated when unfamiliar terms are used in exercises that they are required to complete.
			
			Examples reduce cognitive load.
			
			The paper-based exercises served to facilitate group discussion and an exploration of various communication concepts and situations.
			
			Providing examples may be an effective way of making the Communications concepts less abstract. The concern, however, is that the example may simply be regurgitated when students are left to explore the concepts on their own. It may inhibit (interfere with) the discovery learning process. The examples need to be designed in such a way that this situation is averted. The examples /scenarios should serve as guidelines without directing the students too definitely
			
			Immediate feedback from the facilitator could provide the support necessary when students

Table 4.6 Conjectures and principles associated with domain awareness (continued)

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	It is advisable to provide students with appropriate paper-based exercises in order to facilitate the acquisition of a foundational understanding of the subject domain. It is advisable to show different video clips in order to highlight discrete concepts. The video clips should depict realistic communication situations. It is advisable to integrate paper-based exercises with the video clips and face to face facilitated group discussions. It is advisable to show the students video clips that portray realistic or authentic Communications situations. It is advisable to break the complex situations depicted in the video clips into sections to facilitate analysis. It is advisable to maintain close contiguity between the viewing of the video clips and the discussion that aims to facilitate the	they should request assistance when they need to. Multiple-choice test items that relate to the video clips should be prepared in order to facilitate a basic understanding of Communications concepts illustrated in them. Video clips should be chosen that highlight different aspects of the subject domain. Each video clip must highlight or enable a discussion on a discrete Communications concept. The facilitator should endeavour to allow the Communications concepts embedded in these realistic video clips to emerge naturally during group discussions. The integrating of face to face facilitation, paper-based exercises and the viewing of video clips depicting realistic situations must be carefully	work through paper-based exercises. The exercises were not so open-ended but contained multiple-choice test items related to a video clip that they were shown. This seemed to facilitate a better understanding of the domain and related an understanding of the domain to the expert system concept and logic. Initially the handouts were considered to be too complex because of their open-ended nature. Scaffolding in the paper-based exercises was achieved by giving the students multiple-choice options from which they could choose an answer. Subsequent exercises were more open-ended in nature (Choose options that relate to the video clip). Progress from guided options (multiple-choice test items) to open-ended where they even formulate their own scenarios. Using different video clips, the facilitator can focus on different Communications concepts. These concepts must emerge naturally, which may involve the facilitator selecting video clips with the different learning points in mind (Bear in mind the different learning points when selecting a video clip). This would facilitate an analysis of various communication situations and then the formation of concepts.

Table 4.6 Conjectures and principles associated with domain awareness (continued)

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	emergence of learning points. It is advisable to allow the learning points to emerge naturally from the group discussions. It is advisable for facilitators to adopt a more constructivists approach to facilitation.	managed. The paper-based exercises can be used to introduce basic concepts to the students. Use the paper-based exercises to supplement the face to face interaction. The learning environment must be structured around face to face interaction at this stage. It is advisable to encourage students to participate actively in group discussions. The learning points should emerge naturally and then made more apparent to the learners during a consolidation and summarising phase. Work through the learning concepts in stages, referring to the video clips to underline and reinforce learning. Refer to the video clips to initiate discussion once the students have gained some insight into the concepts. It is advisable to select video	The discussion of the various communications concepts is rooted or grounded in a realistic situation or a practical demonstration. This realistic situation can be referenced in order to allow learning points to emerge or conceptual understanding to take place. Once they have developed a model of their understanding of various Communications principles that emerged as a result of watching video clips, the students may be ready to formulate their own scenarios and develop models related to these. This was tried in the week previous and considered to be too difficult and disorientating. The video clips may help to situate the learning in a real world context and make the students appreciate the relevance of the learning. These may provide them with insight into the complex nature of communication in a real-life situation. The video clips serve as a useful reference that may reinforce conceptual understanding (grounded the learning) Introducing concepts to students by allowing them to work through paper-based exercises may make the viewing of the video clips more meaningful to the students and then lead to more constructive group discussions.

Table 4.6 Conjectures and principles associated with domain awareness (continued)

Category/codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
		clips that portray realistic communication situations.	Face to face facilitation allows concepts to emerge spontaneously during group discussions. Obtaining feedback from the student group is important if concepts are to emerge spontaneously. The real-life situations depicted in the video clips would help make the concepts less abstract for the students.

A description of the design principles related to domain awareness will now be presented.

4.4.1.4.1 Exploring current understanding

When initially creating an awareness of the subject domain it is advisable for the facilitator to place the learning in a suitable context by exploring the students' current understanding of Communications concepts. The facilitator should avoid offering explanations of these concepts without investigating the students' current or existing knowledge. This exploration can be achieved by conducting brainstorming sessions with the student group. Questions can be asked to probe for understanding and to initiate discussion. By doing this the facilitator can gauge the students' current level of understanding and gain an understanding of where to pitch explanations. These brainstorming activities will also help to make students aware of Communications concepts and serve to orientate students within the learning environment. The discussions that are initiated by the brainstorming sessions should attempt to incorporate explanations of terms used in the domain. Both face to face facilitation and paper-based exercises could be used during this exploration phase.

4.4.1.4.2 Paper-based exercises

It is advisable to provide students with appropriate paper-based exercises in order to facilitate the acquisition of a foundational understanding of the subject domain. The paper-based exercises should be designed to explore the students' understanding and facilitate discovery learning. Introducing concepts to students by allowing them to work through paper-based exercises may make the subsequent viewing of the video clips more meaningful and then lead to more constructive group discussions. Paper-based exercises that require a familiarity with domain-specific terms should be supported by activities that provide students with explanations of these terms. Students become confused and disorientated when unfamiliar terms are used in exercises that they are required to complete. Initially paper-based exercises that are markedly open-ended may prove to be too complex. Scaffolding could be incorporated into these activities by including multiple-choice test items that relate to the video clips from which students can select options that make the most sense to them. Subsequent exercises could be more open-ended in nature. This would allow the students to progress from guided options to an open-ended response that requires them to formulate their own scenarios that explore their understanding of various concepts. This would enable the student to gain a better understanding of the domain and enable them to relate this understanding of the domain to the expert system concept or logic.

4.4.1.4.3 Providing support

Facilitators should avoid assumptions concerning the students' understanding of various terms used in the domain. The facilitator should make the students aware that, even though they need to explore their own understanding and discover information for themselves, they should request assistance when they need to. It is advisable to use examples to clarify concepts and initiate discussions. Providing examples may be an effective way of making the Communications concepts less abstract. The concern, however, is that the example may simply be regurgitated when students are left to explore the concepts on their own. The example may inhibit or interfere with the discovery learning process. The examples need to be designed in such a way that this situation is averted. The examples / scenarios should serve as guidelines without directing the students too definitely.

4.4.1.4.4 Incorporating video clips to facilitate discussion

It is advisable to show the student group different video clips that depict realistic or authentic Communications situations in order to highlight discrete domain-related concepts. These video clips should be selected to highlight differing aspects of the subject domain. This would allow each clip to initiate a discussion on a discrete Communications concept. The realistic or authentic nature of these video clips would allow the discussion of various Communications concepts to be rooted or grounded in realistic situations. The realistic context could be referenced in order to allow learning points to emerge or conceptual understanding to take place. The video clips may help to situate the learning in a real world context and make the students appreciate the relevance of the learning. This may provide them with insight into the complex nature of communication in a real-life situation. These video clips may also serve as useful references that may reinforce conceptual understanding. Paper-based exercises could be integrated with the group discussions initiated by the video clips. The integrating of face to face facilitation, paper-based exercises and the viewing of video clips depicting realistic situations must be carefully managed. The facilitator should adopt a more constructivist approach and endeavour to allow the Communications concepts embedded in these realistic video clips to emerge naturally during discussions. The learners themselves must uncover the learning points with minimal guidance from the facilitator. It is, therefore, essential that the students be encouraged to participate actively in all group discussions as obtaining feedback from the student group is important if concepts are to emerge spontaneously. The learning points that have emerged during the discussions could be made more apparent to the learner during a consolidation process where the facilitator summarises the learning points for the student group. It is advisable to maintain close contiguity between the viewing of the video clips and the discussion that aims to facilitate the emergence of the learning points.

4.4.1.5 Representing understanding (modelling)

An important part of the learning environment formulated by the design team is the inclusion of various activities that would allow the students to represent their understanding of the concepts applicable to the domain. It is considered important to bridge the gap between conceptual understanding and a representation of this understanding as well as to ensure that students are able to formulate logical inferences as part of their representation. Table 4.7 lists the characteristics, procedures and arguments associated with the representation of understanding with regard to the learning environment formulated by the design team.

Table 4.7 The representation of understanding

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments

Representing understanding
• Flow-diagram:
  ○ Group discussion
  ○ Own example
• Natural language
• Scaffolding:
  ○ Bridge the gap
• Group discussion
• Facilitator's role:
  ○ ES Logic
  ○ Refer to flow-diagram
• Thinking
	It is advisable for the facilitator to 'bridge the gap' between the conceptual understanding of domain concepts and a representation of this understanding.
	
	It is advisable to facilitate a seamless progression from conceptual understanding to an articulation or representation of this understanding in the form of a flow-diagram.
	
	It is advisable that the students formulate their own scenario that represents a communication situation and plot an examination of this scenario using a flow-diagram.
	
	It is advisable to give students the freedom to represent their understanding of Communications concepts using natural language in the form of IF THEN statements.
	
	It is advisable for the students to expand their thinking to include authentic communication situations.
		The gap between conceptual understanding and a representation of that understanding can be bridged by drafting a flow-diagram that represents the group discussion pertaining to a Communications concept immediately after the discussion has taken place.
		
		Videos clips depicting realistic situations In which various types of communication are taking place could be shown to the student group. These clips could then be discussed and the facilitator could ask the students questions to facilitate an exploration of various Communications concepts embedded in the video clips. These questions together with the answers obtained from the student group could then be plotted on a flow-diagram that could be converted into an expert system.
		
		Once they have understood or appreciated the link
			By allowing an unscripted discussion to be developed or to be transformed into a flow-diagram that can then be converted into a functioning expert system may encourage students to consider the process to be an authentic or accurate reflection of their understanding. They may, consequently, be encouraged to recognise this representation as a true expression of their socially constructed experience.
			
			The contiguity of the discussion of the concept and the representation of the concept using a flow-diagram enables the student to understand the logic behind using a flow-diagram to represent their understanding. It creates a more concrete or obvious link between the concept and its representation.
			
			Plotting an examination of a communication scenario created by the students facilitates an exploration of the students' individual understanding and a representation of that understanding. This is a more hands-on and independent approach to modelling understanding.
			
			The drafting of a flow-diagram that models conceptual understanding facilitates the link between theory and practice. Realistic video clips could be seen as an instance of communication in practice and the flow-

Table 4.7 The representation of understanding (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	It is advisable for the facilitator to ensure that the expert system developed by the students does involve inferences and do not simply put together aggregations of options selected. It is advisable for the facilitator to encourage the students to formulate questions that explore the subject domain appropriately. The facilitator must ensure that the expert system developed by the students do involve inferences and do not simply put together aggregations of options selected. It is advisable for the students to expand their thinking to include authentic communication situations.	between a conceptual understanding and a representation of this understanding they can proceed to represent a scenario informed or inspired by their own experience using a flow-diagram. In order to formulate appropriate questions, the developer needs to have a certain level of insight into the subject domain. The developer needs to explore the subject domain in order to formulate appropriate questions. This insight is further explored and enhanced when the developer is required to infer advice from combinations of answers. Deficiencies in the logic of the flow-diagram are revealed when students undertake the development of a functional expert system. The student need to realise that the expert system must not just provide the user with	diagram could be seen as an abstract representation of concepts relevant to this communication. Representing conceptual understanding using a flow-diagram should not present the students with an unnecessary learning curve. They may feel more comfortable using natural language to represent this understanding. The flow-diagram should be used to help students during the design phase of the expert system development. Some students may not find representing their understanding in this way to be helpful. These students may prefer to use 'natural language' to do so. The development or formulation of the questions helped to make the construction of the flow-diagram seem natural. The formulation of the questions developed naturally from the group discussion / activity. This separation of question formulation and flow-diagram construction may relieve the intrinsic cognitive load associated with putting together a flow-diagram that represents the students' conceptual understanding of various Communications concepts. Intrinsic cognitive load is reduced by allowing for the development of the questions before the drafting of the flow-

Table 4.7 The representation of understanding (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
		an aggregation of the options chosen but needs to make inferences in the way a human expert would. A certain amount of logical thinking would be necessary if an individual engages with an authentic situation (function successfully within an authentic situation). Expand thinking to include the logic that real-life would demand of an individual. Students have to explore their understanding of a subject domain. They apply their understanding to the development of a functional expert system. Construct a representation of their understanding.	diagram. The logic of the questions is applied to the drafting of the flow-diagram. This would guide students through the thought process that needs to be followed to draft a flow-diagram that articulates the logic of an expert system. Formulate questions that can be asked to explore various Communications concepts embedded in realistic communication situations. Use these questions to construct an algorithmic flow-diagram. The subtle guidance will allow the students to see the process as less contrived and artificial. This may help them appreciate the relevance and serve as a source of motivation. Subtle natural guidance prevents students from wondering what the learning agenda might be. Natural progression from general group discussion to a realisation of the logic of an algorithmic flow-diagram. The natural progression may serve to prevent excessive cognitive load. The complexity of the domain becomes apparent through the process of developing an expert system that is designed to mimic the expertise of a human expert. This design and development facilitate a deeper exploration of the domain.

Table 4.7 The representation of understanding (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
			Developing the expert system using the expert system shell facilitates a deeper exploration of the subject domain. This development facilitates a closer examination of the logic expressed in the initial design. The development of an expert system that facilitates a process of reflection. This encourages them to reflect on the subject domain. Forces or encourages the student to think logically about a particular subject or concept. The development of the expert system highlights faulty or illogical thinking. Explores the gaps in one's logical understanding of a concept. Encourages the developer to visualise or explore a real-life or authentic situation and appreciate the logic that an authentic situation would demand or impose on an individual's understanding. Exploring the logic necessary to develop the expert system encourages one to explore one's conceptual understanding of the domain. New way of looking at or thinking about a subject allows the developer to make unexpected discoveries. The understanding or realisation of what an

Table 4.7 The representation of understanding (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
			expert system is allows or encourages the student to consider the subject domain with greater insight. Encourages a deeper more inclusive or comprehensive insight into the subject domain. Considers the subject domain from different angles. Formulating the content of the display line is where the real deep learning is going to take place.

4.4.1.5.1 Bridging the gap between conceptual understanding and a representation of this understanding

When students are required to represent or create a model of their understanding it is advisable for the facilitator to bridge the gap between conceptual understanding and the representation of this understanding. Videos clips depicting realistic situations in which various types of communication are taking place could be shown to the student group. These clips could then be discussed and the facilitator could ask the students questions to facilitate an exploration of various Communications concepts embedded in the realistic video clips. These questions together with the answers obtained from the students could then be plotted on a flow-diagram that could be converted into an expert system.

A seamless progression from a conceptual understanding to a representation of this understanding can be facilitated by drafting a flow-diagram that represents the group discussion pertaining to a Communications concept immediately after the discussion has taken place. This could form part of a consolidation exercise. By allowing an unscripted discussion to be developed or transformed into a flow-diagram that can then be converted into a functioning expert system may encourage students to consider the process to be an authentic or accurate reflection of their understanding. The subtle guidance will allow the students to regard the process as less contrived and artificial. This may help them appreciate the relevance and serve as a source of motivation. They may, consequently, be encouraged to recognise this representation as a true expression of their socially constructed experience.

The contiguity of the discussion of the concept and the representation of the concept using a flow-diagram enables the student to understand the logic behind using a flow-diagram to represent their understanding. It creates a more concrete or obvious link between the concept and its representation and may serve as a guide to the thought process that needs to be followed to draft a flow-diagram that articulates the logic of an expert system. The drafting of a flow-diagram that models conceptual understanding facilitates the link between theory and practice. The realistic video clips could be seen as an instance of communication in practice and the flow-diagram could be seen as an abstract representation of concepts relevant to this communication.

4.4.1.5.2 Formulating and representing scenarios

Once the students have understood or appreciated the link between conceptual understanding and a representation of this understanding they can proceed to represent a scenario informed or inspired by their own experience using a flow-diagram. Students should be encouraged to expand their thinking to include authentic communication situations and to formulate questions that explore the subject domain appropriately. This would encourage them to reflect on the logical thinking and common sense that a real world situation would demand of them.

4.4.1.5.3 Question formulation

It may be constructive to separate the formulation of the questions initially from the drafting of the flow-diagram. This separation of question formulation and flow-diagram construction may relieve the intrinsic cognitive load associated with putting together a flow-diagram that represents the students' conceptual understanding of various Communications concepts. Representing conceptual understanding using a flow-diagram should not present the students with an unnecessary learning curve.

4.4.1.5.4 Using natural language (pseudo-code) to represent expert system logic

Students may feel more comfortable initially using natural language to represent their understanding. Once the logic of their expert system design has been expressed in natural language they can then proceed to draft a flow-diagram.

4.4.1.5.5 Formulating inferences

It is essential for the facilitator to ensure that the flow-diagrams and the actual expert system developed lead to properly or logically formulated inferences and do not simply lead to an aggregation of options selected. In order to formulate appropriate questions the developer needs to have a certain level of insight into the subject domain. This insight is further explored and enhanced when the developer is required to infer advice from combinations of answers. The inferences drawn will eventually form the content of the display line of the functioning expert system and formulating these inferences is where the deepest or most meaningful learning will take place.

4.4.1.5.6 Modeling understanding through the development of a functional expert system

Once an initial draft of the expert system has been plotted using a flow-diagram, it is advisable for the students to undertake the development of the expert system using an expert system shell. This facilitates a close examination of the logic expressed in the initial design and often deficiencies in the logic of the flow-diagram are revealed when they undertake the development of a functional expert system. The complexity of the domain becomes apparent through the process of developing an expert system that is designed to mimic the expertise of a human expert. This design and development also lead to a deeper exploration of the domain and encourage the developer to reflect on the subject domain at a higher, more comprehensive level. Exploring the logic necessary to develop the expert system encourages the developer to explore their conceptual understanding of the domain and facilitates a new way of looking at or thinking about a subject and allows the developer to make unexpected discoveries.

4.4.1.6 Development of a functional expert system

Closely related to a representation of understanding is the actual development of a functional expert system. Students need to be guided toward an understanding of how to convert a conceptual appreciation of the logic applicable to an expert system into an operational application using an expert system shell. This involves a hands-on application of knowledge and carefully managed group collaboration. Table 4.8 lists the characteristics, procedures and arguments associated with the development of an expert system using an expert system shell.

Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
Development • Scaffolding: ○ Decrease • Evaluation • Group interaction • Problem statement • Facilitator's role	It is advisable to give the students something meaningful to develop in order to gain a proper understanding of how to use the development environment. It is advisable that students work independently in groups to develop an expert system once they have gained initial insight into the development process. It is advisable to facilitate development of a functional expert system that is based on the flow-diagram constructed by the student group. The first development exercise can be done as one large group but it is advisable to follow this up with a similar exercise where the development takes place in smaller groups where each individual student will have an opportunity to participate. Evaluating the expert system can be accomplished by asking other groups to use it to solve a communication problem. It is advisable that students be	A simple example, that includes as many of the elements of the software as are necessary in order for them to develop their own expert systems, should be demonstrated to the students on a face to face basis. The handout should be designed in such a way that it can function as a reference for students when they begin their own development. Examples should also be used when explaining terminology. The problems presented to the students should initially be very simple and well structured. As the students progress the problems presented to them can become more ill structured. The previous contact session required the group to formulate questions in order to explore a particular Communications concept or concepts imbedded within	It may be difficult and impractical to anticipate all issues / concerns / problems / difficulties that the students may have and include them in a comprehensive handout or step by step guide. Working through examples on a face to face basis will allow the facilitator / lecturer to address these issues as they arise. English language proficiency is often a problem among first year students at TUT. This could prove to be a significant obstacle to the students' grasp of information if the language used in the handouts is not at an appropriate level. If the problems presented to the students are too difficult and ill structured the students will focus on the problem and not on how to learn to use the software. The more familiar the students become with the software the more ill structured the problems can become. Face to face facilitation is important when the students are first exposed to the learning environment and are introduced to the expert system concept and the expert system shell (CourseLab). A handout, irrespective of its detail, is insufficient at this stage of the students 'exposure to the learning environment. Using examples in both handouts and face to face demonstrations will assist the students

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Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	made aware of how their expert systems will be assessed. It is advisable to allow different groups to work separately on the same task and then at the end of each development or planning session for various groups to get together to discuss their individual development. It is advisable not to allow too much time to elapse between a demonstration of how to develop an expert system using the expert system shell and when the students start developing their expert systems. It is advisable for the facilitator to be on hand to refresh the students' memories when they begin the development (begin to interact with the expert system shell). It is advisable that the facilitator does not assume that the students fully understood the coding conventions when these were demonstrated to them. It is advisable for the facilitator to ensure that all students are	video clips. An algorithmic flow-diagram was then drafted using the questions and answers prepared in the proceeding step. This flow-diagram was then used as the basis for the development of a functioning expert system using CourseLab as an expert system shell. Students were first prompted to make a contribution to this development through probing questions from the facilitator and then invited to sit at the workstation on which the development was taking place and, with guidance from the student group, continue the development. It may be advisable to work through the development with the student group in order to refresh the students' understanding of how to use the expert system shell. This is particularly important for those who have not had much exposure to a similar development environment.	to grasp concepts. Students will consolidate their understanding when they attempt hands-on development. They will gain a better more accurate understanding of the design and development process once they start to work on their own. Preceding steps make the process logical, (I.e. an understanding of flow-diagram symbols and expert system logic) Situating the learning within authentic or realistic settings may make the learning more relevant to the students. The learning is situated within settings that the students are better able to relate to. The progression from formulating questions to drafting a flow-diagram to developing a flow-diagram was designed to articulate the link between conceptual understanding and the development of a functioning expert system. Looking at the development taking place gives the learner an idea of what is going on but the real understanding or a confirmation of understanding takes place only when the learner attempts the development him- or herself. .

Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	involved in the hands-on development of the expert system. It is advisable that the facilitator ensure that the students have a clear understanding of the logic applicable to expert systems. It is advisable for the facilitator to encourage the students to refer to their flow-diagrams during the development of the expert system. It is advisable for the facilitator to encourage students to revise their expert system when necessary.	A data projector was used for this demonstration / group development. Taking over or controlling what appears on the monitor at each student's workstation would allow students to see the development taking place clearly and would also allow them to try certain aspects of the development on their own. This would be particularly useful for larger groups where students are likely to disengage if they are not able to follow the development process easily. The response from the student group will give the facilitator insight into their level of understanding. The facilitator would need to be sensitive to this awareness and facilitate the development process accordingly. Students must be encouraged to participate actively in the development process. It must be emphasised that they will not	The development of the expert system facilitates a close examination of the logic of the algorithmic flow-diagrams that were formulated during the design phase. It also allows for an examination of the validity of this logic. The group collaboration allows for mutually constructed understanding and peer support. Individuals within the student group have different levels of experience and understanding; collaborating allows for individuals to support one another. The facilitation needs to be appropriate to the needs of the students. The lecturer would need to be responsive to the feedback obtained from the student group and adjust the level of support appropriately. By allowing the different groups to get together after each development session would facilitate the comparison and contrasting of ideas and understanding. Take the best of all the development activities to reinforce conceptual understanding. Facilitate the exchange of ideas. A lack of exposure to a programming environment leads to confusion. Too much time elapsed between the

Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
		learn or achieve anything if they do not participate constructively. The display line or output of the expert system will indicate whether the students have understood the logic of an expert system. The flow-diagram lays the foundation for the development. It is important that the students understand what an expert system is. It is not a summary of various options selected but involves inferences made as a result of options selected.	demonstration of inserting code statements in the expert system and when the group needed to develop their own expert system. Even notes did not make sense; the facilitator needs to be on hand to provide assistance when the students begin to interact with the expert system shell. The facilitator must not assume that the students will fully remember how to insert coding statements and how to structure coding statements. The facilitator must be aware that students may not be familiar with coding conventions or concepts and must be on hand to assist. The practical development of the expert system is important for the understanding of expert system logic. The concepts are not fully grasped when members of the group are simply observing the development process taking place. Learning is enhanced when students are encouraged to be directly involved in the development process. Students may not fully understand the concepts being explored unless they are directly involved in the development process. Mistakes force the learners to revisit, not only the coding syntax, but also the logic of their expert systems. Students learn from these mistakes and revise thinking.

Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
			The display line or output of the expert system will indicate whether the students have understood the logic of an expert system. It seems to be common for the developer to assume that the advice offered by the expert system involves an aggregate of the options selected by the user. The concept of an inference engine needs to be carefully explained. The development of the expert system using CourseLab as an expert system shell demonstrated faulty logic. The development process encouraged the students to examine the logic of their expert system design more closely. The faulty logic was revealed during the development process. The development of the expert system revealed errors in thinking and often extended the thinking process. Because the students have to apply the design, often faulty, incomplete or deficient logic is exposed. Even mistakes made during the coding process encourage students to re-explore the logic of the domain. The learner (developer) would need to examine both the code and the flow of logic applicable to the domain in order to discover the reason for a particular

Table 4.8 The characteristics, procedures and arguments associated with the development of an expert system (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
			output (result, consequence). Constant problem-solving encourages higher-order thinking. Revisiting programming code to discover faults or to determine why the program is not working as it should requires constant problem solving. Becoming familiar with the development environment detracts from the conceptual exploration of the domain. Working on the inferences that need to be drawn by examining the choice combinations is where the bulk of the higher-order thinking takes place

4.4.1.6.1 Students' initial exposure to developing an expert system

When students are introduced to the development of a functional expert system it is advisable for them to work together as one large group. This group development would need to be supported by face to face facilitation and could consist of converting the flow-diagram constructed by the student group (see paragraph 1.5) into a functional expert system. The facilitator could also use a simple example that highlights both the functionality of the expert system shell and the terminology used in the development environment to support the students' understanding of the development process. The worked example may help to reduce the cognitive load associated with learning to use the expert system shell. Once they have undertaken the large group development exercise, the students should be divided into smaller groups where each individual group member can have an opportunity to participate actively in the development process. It is advisable to give the students something simple but meaningful to develop at this stage. If the problem presented to the students is too difficult and ill structured, the students will focus on the problem and not on how to use the expert system shell. The more familiar the students become with the software the more ill structured the problem can become.

4.4.1.6.2 Group collaboration and reflection

It is advisable to organise the learning environment in such a way that different groups work separately on the same task and then, at the end of each development or planning session, for these groups to get together in larger groups to compare and contrast their separate development activities and ideas. The individual groups could then take the insights gained from the larger group discussion and modify their own development ideas accordingly. The facilitator would need to manage the group division process carefully to avoid confusion and to ensure that the interaction between the groups is as productive as possible. It may be helpful to draft a group register and to use this register to organise the students into larger groupings at the end of each design and development session. A paper-based group reflection exercise could be used to facilitate constructive interaction in the larger groupings. This exercise could include the following probing questions:

- What were the differences between what your group did and what the other groups did during the design / development session?
- What did you learn from these differences?
- How are you going to use what you have learnt in your own expert system design?

This type of collaboration allows for mutually constructed understanding and peer support. Individuals within the student group have different levels of experience and understanding; collaborating allows for individuals to support one another.

4.4.1.6.3 Development of a functional expert system based on flow diagram design

The development activities should be based on the design ideas formulated when the flow-diagrams were drafted. The facilitator must encourage the students to refer constantly to these flow-diagrams during the development of their expert systems. They should also be advised that it is essential to be open to the revision of design ideas, as it may happen that when they have to apply their designs faulty, incomplete or deficient logic is exposed.

4.4.1.6.4 Familiarity with the expert system shell

It is advisable for the facilitator not to assume that the students are completely familiar with how to use the expert system shell when they start their development, even after this has been systematically demonstrated to them. This is especially true if a significant amount of time has elapsed since the demonstration. It is advisable for the facilitator to summarise how to use the software. The coding conventions and terminology applicable to the expert system shell are particularly important in this regard. It may be useful to revisit the worked examples demonstrated to the students earlier.

4.4.1.6.5 Active participation in the development process

The facilitator must attempt to ensure that all students actively participate in the development process. It must be emphasised that they will not learn or achieve any real benefit if they merely watch other members of the group put together the expert system.

4.4.1.6.6 Development must reflect expert system logic

It is important for the facilitator to ensure that the students have a clear understanding of what an expert system is. The concept of inference needs to be carefully explained to the student group as students may be inclined to construct or design an application that simply creates an aggregate of options selected. They need to be aware that the expert system should be designed to generate recommendations and suggestions based on various combinations of options. It is advisable for the facilitator to monitor the students' progress and pay particular attention to the display line of the application. Even before the development has progressed to a point where an output has been generated by the application, the facilitator should ask the students what they understand the output of their expert systems should be. This will give the facilitator a clear appreciation of whether the students comprehend the concept of inference. It may be necessary to point out deficiencies in the logic of their development but the facilitator must be careful not to be excessively directive. It may be useful to point out that a human expert would not simply summarise or aggregate information obtained but would take the information and use it to draw conclusions that would be helpful to a non-expert or a person seeking advice.

4.4.1.7 Students' engagement with the problem statement

An essential aspect of the learning environment is the students' interaction with the problem that their expert system needs to address. Table 4.9 lists the characteristics, procedures and arguments associated with the students' interaction with the problem.

Table 4.9 The characteristics, procedures and arguments associated with problem interaction

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments

Problem interaction
• Problem statement:
  ○ Composition
• Support:
  ○ Facilitation
	It is advisable that the problem presented to the students be situated within a realistic set of circumstances (Scenario).
	
	It is advisable that the scenario in which the problem is situated allows for the learning outcomes to emerge.
	
	It is advisable for the facilitator to guide the students towards the understanding that the solution to the problem involves an exploration of various Communications concepts.
	
	It is advisable for the facilitator to perform a supporting role when the students investigate a solution to the ill structured problem.
	
	It is advisable to formulate the problem in the form of a brief that outlines a concept rather than one that describes a particular situation.
	
	It is advisable to include background information that the students can refer to in the brief.
		The scenario in which the ill defined problem is imbedded must be designed to allow for the learning outcomes to emerge.
		
		The solution to the problem (dilemma) must not be obvious or prescriptive.
		
		Without being prescriptive or overly directive the facilitator must ensure that the students detect the Communications concepts embedded in the ill structured problem.
		
		Guidance needs to be given in terms of what an expert system is.
		
		All progress evaluation should be evaluated in terms of the students understanding of the expert system concept.
		
		The facilitator must provide the learners with guidance by questioning their thinking or posing questions that stimulate thinking and provides guidance. The facilitator must not provide the students with direct answers to questions but must provide guidance concerning along which
			This would make the task more authentic and test the validity of the expert system logic effectively.
			
			A rubric may be too prescriptive. The application developed must be an expert system that is comprised of the various components of an expert system. Their applications must not be an aggregate of the various options selected but must rather be a ‘reasoned’ response to a problem outlined by a novice user. Students must clearly understand what an expert system is and that effective progress in their development is dependent on this understanding.
			
			The facilitator must ensure that the students grasp the rationale behind the ill-structured problem.
			
			Problem must be situated within a realistic situation or set of circumstances.
			
			The open ended or ill defined nature of the scenario might allow for broad understanding of Communications concepts. The solution to the problem is not implicit in the scenario so that learning outcomes are not dictated or restricted.

Table 4.9 The characteristics, procedures and arguments associated with problem interaction (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
	When students begin to explore a solution to the open-ended problem, it is advisable for the facilitator to be available to provide guidance and direction to the students. It is advisable for the facilitator to make the students aware that they are free to seek guidance from the facilitator. It is advisable to incorporate background information into the problem statement that students can refer to.	lines they should be thinking. The facilitator must not be too meddling and intrusive; he must respond to the students' enquiries rather than impose his advice on them. The facilitator must ensure that the design and development do explore appropriate Communications concepts. The facilitator must carry out sufficient monitoring to ensure that the students are exploring and representing appropriate Communications concepts. Instead of describing a particular situation, provide the students with a brief that outlines a concept. The problem statement should be in the form of a brief that outlines a concept. It should not be in the form of a clear-cut scenario where a solution is implied by the situation itself. It should be open-ended and be able to accommodate a variety of approaches.	A problem with an obvious solution may not elicit a representation of the students' understanding and will lead to duplication or regurgitation. The ill defined problem must allow for the emergence of the desired Communications concepts; it must accommodate the emergence of these concepts. The problem is not situated within an artificial scenario but rather in the form of a conceptual brief that could be applicable to a variety of situations. The brief provides background information to the concept that needs to be explored; it sets the scene without hinting at an obvious solution. An obvious problem is not imbedded in the problem statement. The problem statement presents the students with a broad outline of a situation that is reasonably intangible. The problems are more of a conceptual nature and are not rooted in the particulars of a situation. Students are able to explore their understanding more effectively when they are provided with a problem that sketches a broad set of circumstances

Table 4.9 The characteristics, procedures and arguments associated with problem interaction (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
		The facilitator must be available to provide the students with prompt guidance. When a question or impasse occurs, the facilitator must be on hand to provide prompt advice and direction. Even though the students are required to design and develop an expert system on their own with reference to an ill-structured problem statement, they should be encouraged to pose questions and request guidance from the facilitator. Even though they are required to design a solution on their own, they must be given the freedom to ask questions when they require assistance. The problem statement provides a reasonably detailed amount of information that students can refer to when exploring their own understanding or when exploring possible solutions to the problem.	that could be applicable in a variety of situations. Their exploration of the domain is not confined to the details imbedded in an artificially contrived scenario. The open-ended nature of the problem statement allows or accommodates a variety of solutions. There is no obvious answer. The open-ended nature of the problem statement may disorientate students. These students may require guidance from the facilitator to avoid becoming disillusioned. It is advisable for the facilitator to provide timely guidance. Feedback from the students in the form of questions and requests for guidance will give the facilitator an indication of what sort of scaffolding the students require and will place the facilitator in a better position to assess the students' cognitive understanding. The problem statement was presented to the students after they had been given an opportunity to work through a worked example. This placed them in a better position to formulate / undertake /

Table 4.9 The characteristics, procedures and arguments associated with problem interaction (continued)

Category / codes	Characteristics (substantive emphasis)	Procedures (procedural emphasis)	Arguments
			develop a solution to the problem. This provided them with insight into how to approach the ill defined problem statement. Provides background, conceptual information to allow the students to gain a greater insight into the problem. Allowing progress toward a more focused problem once the background to the problem has been provided. Working through the examples provides the students with insight into various ways to address the problem without providing them with definitive solutions. This involves the progression from working together with the facilitator to developing a simple example to working in small groups to design a solution to an ill defined problem. The facilitator can gauge the level of scaffolding required by the students through the questions that they ask. The learning environment must encourage the students to ask for assistance when they need it.

It is advisable that the assignment that is presented to the students contains a problem that is situated in a realistic setting or scenario. This problem must initiate or allow for the emergence of learning points within the appropriate subject domain. The solution to the problem must not be obvious and should be formulate in the form of a brief that outlines a concept rather than one that describes a particular situation that has a single implied solution. Students are able to explore their understanding more effectively when they are provided with a problem that sketches a broad set of circumstances that could be applicable in a variety of situations. Their exploration of the domain will consequently not be constrained by the details imbedded in an artificially contrived scenario. The open-ended nature of the problem statement allows or accommodates a variety of solutions.

The open-ended nature of the problem statement may, however, disorientate students. These students may require guidance from the facilitator to avoid becoming disillusioned and confused. The facilitator must be available to provide the students with prompt assistance. When a question or impasse occurs, the facilitator must be on hand to provide prompt advice and direction.

Feedback from the students in the form of questions and requests for guidance will give the facilitator an indication of what sort of scaffolding the students require and will place the facilitator in a better position to assess the students' cognitive understanding.

It is important that the facilitator should ensure that the solutions that the students design do indeed explore Communications concepts. Without being prescriptive or overly directive the facilitator must ensure that the students detect the Communications concepts embedded in the ill structured problem. It is advisable for the facilitator to guide the students towards an understanding that the solution to the problem involves an exploration of various Communications concepts. The facilitator must provide the learners with guidance by questioning their thinking or posing questions that stimulate thinking. The facilitator must not provide the students with direct answers to questions but must provide guidance by indicating along which lines they should be thinking.

4.5 Chapter summary

This chapter begins with an overview of the main points of interest applicable to this study and how these are to be explored by presenting a prototype of a learning environment that involves using technology as a cognitive tool to a team of lectures and instructional designers. The environment was presented to this team in order to refine the environment and formulate relevant conjectures and principles. A table that illustrates the substantive themes that emerged during each of the design sessions held with the design team is then presented. This table is followed by a description of the learning environment that evolved from these design sessions.

During the description of the learning environment, the context in which the environment was placed is outlined by briefly describing the subject content and indicating the course that it forms part of. The environment itself is then described by breaking it up into seven broad sections.

Under the section *Initial exposure to the learning environment* undertakings concerning the students' introduction to the learning environment were outlined. In the section headed *Presenting the ill structured problem* activities related to guiding the students toward an understanding of the ill structured problem were presented. In *Explicating the expert system concept* section issues related to the students' understanding of the definition, components and roles related to expert systems are discussed. Activities related to demonstrating or presenting the students with an example of a functional expert system are outlined in the section headed *Demonstrating a functional expert system*. Issues related to explaining and demonstrating how to express the logic of an expert system are presented in the section headed *Explaining flow-diagram representation*. Activities concerning relating and exploring the subject content through the use of flow-diagrams is outlined in the section headed *Exploring the subject domain using an algorithmic flow-diagram*. The description of the learning environment ends with an outline of activities related to modelling understanding by exploring the ill structured problem.

The way in which the conjectures and principles were determined and formulated is then briefly described. The design principles in the form of conjectures and principles are then presented under the following broad headings:

- Initial exposure to the learning environment
- Discovery learning
- Designing the expert system
- Creating subject (domain) awareness
- Representing understanding (modelling)
- Development of a functional expert system
- Students' engagement with the problem statement

Chapter 5

Data analysis and findings

Exploring the experiences of students

5.1 Introduction

Chapter 4 presented the data analysis and findings related to the first research question, namely, *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 English Communications students at TUT?* The second part of the research was aimed at exploring how students experienced the learning environment to which the conjectures and principles outlined in Chapter 4 are applicable. Exploring the students' experiences of the learning environment allows for a better apprehension of the value and validity of the conjectures that informed or gave substance to the design of the learning environment. This exploration may also provide insight into the extent to which the conjectures are substantiated by practical experience. In addition, this exploration may give direction to potential modifications and improvements to the environment.

5.2 How will foundation students experience a learning intervention that uses technology in the form of an expert system shell in order to develop higher-order thinking skills?

What follows is a description of the findings that have resulted from a grounded theory analysis of transcripts of focus group interviews (see Addendum G) conducted with these students.

5.2.1 Setting the scene

In order to address the second research question, two groups of Foundation English Communications Skills students were exposed to the learning environment described in 4.3. This intervention took place over an eight-week period and consisted of 12 contact sessions, half of which were held in a computer laboratory. Four focus group sessions (two per group) were held with these two groups; one set of interviews was conducted two weeks into the intervention and another at the end of it. Transcriptions of these interviews were used as the basis for the grounded theory analysis. Open, axial and selective coding were used to analyse these transcriptions.

5.2.2 Fragmenting the data into labels and formulating categories

Sentences and fragments were labelled using the application Atlas.ti and through a process of constant comparison these labels were organised into more abstract categories or higher level codes. These categories together with the applicable codes are listed in table 5.9.

Table 5.9 Categories and their related codes formulated from analysis of focus group interviews held with students

Higher-level code or category	Code
Extend thinking	Apply learning Reflection More difficult than expected Logical thinking Think outside the box Out of comfort zone Flow-diagram Difficult for the designer Giving advice when still learning Understand the problem Learning by developing Apply understanding to development Own ideas Broadened understanding Broader mind Compare understanding Consider the end user Disagreement encourages thinking

Table 5.9 Categories and their related codes formulated from analysis of focus group interviews held with students (continued)

Higher-level code or category	Code
Extend thinking (continued)	Expanded awareness Improve understanding Learning by struggling Open-mind Posing questions Think like experts Transfer learning to different settings
Challenging learning environment (Demanding greater cognitive engagement)	Don't know where to start Complicated Challenge for non-IT students Cognitive challenge Consider the end user Difficult for the designer Easier to listen to lecture Flow-diagram Learning to use the software Using the software More difficult than expected More practice Time Working in groups
Collaborating in groups	Compare understanding Consult with group members Convince group members Different ideas Disagreement encourages thinking Feel used by group members Group agreement Group debate Group decision-making Group disagreement Group members' lack of contribution Group members not learning
Disagreement among group members	Convince group members Disagreement encourages thinking Disagreement leads to better end results Group decision-making Different ideas Group disagreement
Positive attitude	Attitude Enjoyable Exciting Interesting
Learning through development	Applying learning to development Linking technology to learning Paper-based Planning Posing questions Practical application Using knowledge gained to develop expert system
The representation of understanding	Apply understanding to development

Table 5.9 Categories and their related codes formulated from analysis of focus group interviews held with students (continued)

The representation of understanding (continued)	Individual representation of understanding Options Posing questions Using knowledge gained to develop a functional expert system

5.2.3 Exploring the relationships in the data

A thorough analysis was performed of each category identified during the open coding phase of the data analysis. A coding paradigm was used as a guide during this process. Causal conditions that gave rise to the occurrence of the category / phenomenon were investigated, the phenomena themselves were established, attributes of the context were explored by examining the set of facts or circumstances that surrounded the phenomena, intervening conditions were investigated, action / interaction strategies that were formulated by the actors to handle the phenomena were explored and the consequences of these strategies were looked at during this phase of coding. Table 5.10 outlines the results of this analysis.

Table 5.10 Axial coding — Student group

Phenomena	Causal conditions	Attributes of context	Other intervening conditions	Action / interaction strategies	Consequences of the action / interaction strategies
Extend thinking (Encouraging extended thinking) Properties: • Transferability • Level of difficulty • New ways of thinking • Retention • Types of thinking: ○ Logical ○ Critical	Application of learning Reflection More difficult than expected (exposure to a learning environment that was more demanding than expected). Difficult for the designer (the challenges inherent in designing the expert system as opposed to just using it). Giving advice while still learning. Learning by developing. Consider the end user. Disagreement encourages thinking. Learning by struggling. Posing questions.	Group discussion Group assignment Computer laboratory sessions Non-laboratory contact sessions		Logical thinking Move out of comfort zone. Applying understanding to development. Compare understanding. Think like experts (to develop the ES). Transfer learning to different settings.	Think outside the box (thinking in new ways, seeing things from unfamiliar perspectives). Deeper understanding of the problem Own ideas Broadened understanding Broader mind Expanded awareness Improved understanding Open mind

Table 5.10 Axial coding – Student Group (continued)

Phenomena	Causal conditions	Attributes of context	Other intervening conditions	Action/interaction strategies	Consequences of the action / interaction strategies
Demanding *(greater)* cognitive engagement Challenging learning environment Challenges presented by the learning environment. Properties: • Learning task (assignment) • Using the software • Level of experience • Level of guidance • Time	Don't know where to start (not knowing where to start or being left alone to figure out where to start contributes to the phenomenon occurring). Complicated (complex) Challenge for non-IT student (Computer programming experience/knowledge). Difficult for the designer (more difficult to create than to use). Easier to listen to lecture (just looking is easier than having to create, less of a challenge). Flow-diagram (having to draft a flow diagram presented challenges). Presentation of the programming syntax (was not presented in such a way that the students could easily	Group discussion Group assignment Computer laboratory sessions Non-laboratory contact sessions	Learning how to use the software. Using the software (there were challenges inherent in learning and using the software but this needed to be done before something new could be created, before the cognitive challenge really began). More practice More practice exercises	Cognitive challenge (learn something new, challenge ourselves, creating is challenging. In response to the phenomena the students challenged themselves, created something new.) Considering the end user (be aware or consider the end product, see things from another perspective). Broader thinking applied. Move out of comfort zone. Think beyond school days. Reflection	More difficult than expected (the learning environment facilitated the challenges and the cognitive challenges were more difficult than expected; creating something is hard). Expanded awareness Think like experts. Transfer learning to different settings.

Table 5.10 Axial coding – Student Group (continued)

Phenomena	Causal conditions	Attributes of context	Other intervening conditions	Action/interaction strategies	Consequences of the action / interaction strategies
	see IF THEN statements clearly). Time (pressure of getting things done within a limited amount of time). Working in groups (cooperation a problem).				
Phenomena	**Causal conditions**	**Attributes of context**	**Other intervening conditions**	**Action/interaction strategies**	**Consequences of the action / interaction strategies**
Collaborating in groups Working together in groups	Group assignment Different levels of understanding	Group assignment Computer laboratory sessions Non-laboratory contact sessions The practical development of an expert system in and out of a computer laboratory	Disagreement encourages thinking Feel used by group members Group disagreement Group members' lack of contribution	Compare understanding. Consult with group members. Group decision-making	Different ideas Group agreement Group members not learning

Table 5.10 Axial coding — Student Group (continued)

Phenomena	Causal conditions	Attributes of context	Other intervening conditions	Action / interaction strategies	Consequences of the action / interaction strategies
Disagreement among group members	Group assignment Different ideas See things differently Working with different people Group disagreement	Group assignment Computer laboratory sessions Non-laboratory contact sessions The practical development of an expert system in and out of a computer laboratory		Convince group members Group decision-making	Disagreement encourages thinking. Disagreement leads to better end results. Not getting the job done.
Phenomena	**Causal conditions**	**Attributes of context**	**Other intervening conditions**	**Action / interaction strategies**	**Consequences of the action / interaction strategies**
Positive attitude Properties: • Enjoyment • Excitement • Interest Challenging	Novelty Developing something Interesting Provides a challenge Linking technology to learning Learning through development Combine knowledge	Development of an expert system Laboratory sessions Group assignment			

Table 5.10 Axial coding — Student Group (continued)

Phenomena	Causal conditions	Attributes of context	Other intervening conditions	Action / interaction strategies	Consequences of the action / interaction strategies
Representing understanding Properties: • Expert system • Flow-diagrams • Questions • Options	Apply understanding to development of an expert system. Using knowledge gained to develop an expert system. Using software (CourseLab)	Development of an expert system Planning Laboratory sessions Group assignment Flow-diagrams		Posing questions Designing options	Development of a communication guideline (the expert system) Thinking about various options/contexts
Phenomena	**Causal conditions**	**Attributes of the context**	**Other intervening conditions**	**Action / interaction strategies**	**Consequences of the action / interaction strategies**
Collaborating in groups Working in groups Properties: • Level of cooperation (working together — no contribution) • Decision-making • Level of agreement	Group assignment	The practical development of an expert system in a laboratory and outside laboratory time. Group activity Group assignment Computer laboratory sessions Non-laboratory contact sessions	Group members' lack of contribution Group members not learning	Consult with group members Attempt to convince group members Group decision-making (vote)	Different ideas Group disagreement Disagreement encourages thinking Disagreement leads to better end results

5.2.4 Developing an analytical story – how did the students experience the learning environment?

The main idea that emerged during the coding phases was centred on *working in a learning environment that uses technology as a cognitive tool*. All other categories were related to this core concept. The process employed to refine the description of how students experienced the learning environment that uses technology in the form of an expert system shell to facilitate higher-order thinking made use of several overlapping steps. These involved an explication of the story line in which a general description of the way in which students experienced the learning environment was outlined. The relationship between categories at a dimensional level as well as the way in which they relate to the core category or concept was then outlined. These relationships were validated against the data by extracting salient quotes from transcripts of the focus group interviews held with the student group and incorporating them in a descriptive passage. These steps were not regarded as distinct from one another but together allowed for the development of an analytic story. This analytic story was outlined in a descriptive passage. Table 5.11 outlines the results of this process.

Table 5.11 Selective coding

Selective coding steps	**Central idea: Working in a learning environment that uses technology as a cognitive tool**
Explicating the story line.	The central idea that runs through the coding of the transcripts is the students' experiences of working in a learning environment that uses technology as a cognitive tool. Working within the learning environment provided students with the opportunity to link the learning of communication with technology. This learning environment comprised activities both in computer laboratories and out of computer laboratories. The activities that were not conducted in computer laboratories were used as planning sessions. During these sessions students worked in groups to outline the structure of their expert systems in the form of flow-diagrams and by writing down questions and answers. The drafting of the flow-diagram often encouraged students to think logically about the structure of their proposed expert systems. This was often considered to be the more difficult part of the process and the one that required the greatest amount of thinking. Some students considered the drafting of the flow-diagram to be the most time-consuming part because it involved formulating ideas and the articulation of various options. Other students considered the implementation of the ideas to be more difficult and time-consuming. The non-laboratory contact sessions also provided students with an opportunity to reflect on the development that took place during

Table 5.11 Selective coding (continued)

	laboratory sessions. The flow-diagrams and questions formulated during the planning sessions were used during the laboratory sessions to develop the expert system that represented their understanding of various Communications concepts. Both the planning and development processes required students to collaborate in groups. Students considered the group work to allow for the combining of knowledge and ideas. The group activities also facilitated discussion. A group assignment that consisted of an ill structured problem in the form of a conceptual brief was given to the students. The discussions that resulted from the group assignment led to the generation of different ideas concerning the development of an expert system. These differing ideas were often compared with one another in order to determine the most appropriate option. Sometimes modifications to ideas were made as a result of the process of comparison. The group discussions often led to disagreement among group members. Often group members had to be convinced by others in the group that a certain course of action should be taken. Sometimes a vote was taken when it was necessary for the group to make a decision. The students generally regarded group disagreement in a positive light and were of the opinion that it encouraged deeper thinking and often led to better end results. The discussions that resulted from group disagreement often made students aware of different ways of approaching a problem and of achieving a solution. These discussions also seemed to highlight the need to have a clear understanding of the problem that needed to be solved. It also resulted in a deeper exploration of the individual student's own ideas. The articulation of solutions and ideas highlighted the need to think logically about the subject domain. Disagreement among group members often seemed to lead to a process of reflection and the exploration of alternative ideas. Students, however, sometimes found the various group members' lack of contribution to be frustrating and were concerned that many in the various groups were not really learning anything. Group activities and the resulting disagreements that occurred at times were thought to slow down the development process. Students often considered the linking of technology to the learning of Communications concepts to be a novel approach to learning and as a result found it to be enjoyable, exciting and interesting. They also considered it to be a practical and hands-on approach to learning; this also contributed to it being an enjoyable and interesting experience. Most students found learning by developing something to be an effective way to engage cognitively with the subject. Some students regarded the fact that it provided them with a challenge to be enjoyable and interesting. Linking technology to the learning of a subject such as Communications also seemed to make the subject more relevant to the students as they considered themselves to be part of a project that exposed them to an authentic real world situation. The group activities also made the learning experience enjoyable for most of the students as they gave them an opportunity to combine knowledge and compare understanding. The development of the expert system required students to apply their understanding of various Communications concepts that they learnt about from their lecturers. This often made them realise that they did not know the subject content as well as they thought they did and encouraged them to consider Communications in a broader context. They often considered themselves to be moving outside of their comfort zones during this

Table 5.11 Selective coding (continued)

	process and considered it to be a step above what had been required of them when they were at school. Some students were of the opinion that the task of completing the group assignment forced them to think at a different level and place themselves in a real world context, solving real world communication problems. They admitted that they now see Communications in a far broader light and would now be in a better position to apply the concepts taught during the contact sessions. They generally thought that their communication behaviour would change as a result of working within the learning environment. They indicated that they would now be in a better position to identify communication errors and be able to communicate more effectively in a variety of situations. Many students saw the development of an expert system to result in a guide to inexpert communicators and considered themselves to be in a better position to guide these users themselves. The learning environment seemed to encourage the students to expand their thinking. This environment proved to be more demanding than they expected it to be and presented them with various challenges that they were unaccustomed to. They were not used to representing their knowledge actively and considered a typical lecture to be less demanding. They often found it challenging to assume the role of the designer of an expert system that provided expertise to a non-expert user. The planning and development process prompted the students to consider the perspective of the end user. They felt that it was necessary to anticipate questions and problems that the user was likely to have and to provide answers and solutions to these. This forced them to reflect on their own understanding and encouraged them to see the domain in the way a human expert might see it. This often allowed the students to consider the application of earning in authentic settings and gave them a deeper understanding of how learning could be applied. The students were prompted to think logically in order to develop their expert systems. The planning of the expert systems using a flow-diagram illustrated the flow of logic applicable to the expert system and prompted the students to adapt their thinking according to this. The generation of ideas through group discussion and disagreement prompted students to consider their own ideas as well as those of others in the group critically. The learning environment encouraged the students to think in new ways about a subject that they had previously considered mundane and insubstantial. The learning environment demanded greater cognitive engagement from the students than they were used to and they often felt lost and bewildered in it. The open-ended nature of the group assignment frequently made them feel disorientated and many of them did not know where to start or how to approach it. Some of the students found the software challenging to use while most of them thought it was easy in comparison to other 'programming' languages that they had been exposed to. Their exposure to other programming environments, however, led them to expect the CourseLab development environment to contain certain features and to present programming syntax in specific ways. Because CourseLab is not really a programming environment but rather a course development environment, programming is facilitated by means of a series of dialogue boxes. The end result of this is that the complete flow of the script or program cannot be read easily on one page. The students sometimes found this to be a little disorientating and would have preferred to be able to trace the programming logic (i.e. the IF, THEN statements and the METHODS) in one view. They thought that it might be especially challenging for people who do not have much information technology (IT) or programming experience. There was a sense that they considered themselves to be a select group because they

Table 5.11 Selective coding (continued)

	had had exposure to programming before. The software, nevertheless, did add to the learning load in the learning environment. Many of the students found articulating the logic of an expert system in the form of a flow-diagram to be challenging. Many students considered the lack of available time to be a considerable difficulty. They often seemed to feel pressured to achieve an outcome in an environment that demanded a great deal from them. They would have preferred having more time to tackle practice exercises and to get to know the 'programming' environment better. The students did, however, find the cognitive challenge presented by these difficulties to be enjoyable and rewarding. The group activities became a problem when insufficient cooperation was obtained from some of the group members. Some of the members of the various groups made little contribution to the planning and development of the expert system and proved to be a source of frustration to the others who felt used.
Relating categories at the dimensional level.	All students were required to work in groups during both the planning and development stages. These group planning and development activities seemed to be both a source of frustration and a vehicle that generated ideas and facilitated deeper thinking. Group disagreement emerged as a significant theme and was regarded in both a positive and negative light. The need to justify and substantiate points of view required students to contemplate their ideas more carefully and often resulted in the realisation that there may be more than one solution to a problem. These group disagreements also frustrated some students as they considered them to be an obstacle to the development process. The group activities also seemed to allow some students to hide behind the work of others. The learning environment resulted in students thinking at a different level. Some students were encouraged to think outside their comfort zones while others remarked that they had to apply a greater degree of logical thinking. The group debates and disagreements resulted in students evaluating their own and other members' ideas more critically. They evaluated these ideas in terms of their usefulness and in relation to the utility of other ideas. The students also considered the learning to have real world relevance and considered themselves to be in a better position to identify errors in communication and apply what they had learnt. Learners considered themselves now to be able to think like experts. There was also a sense that they would be able to transfer their insights and understanding to different settings. During the course of the planning and development process the students represented their understanding of various Communications concepts in the form of flow-diagrams, lists of questions and answers, and functional expert systems developed in the CourseLab environment. One of the biggest challenges expressed by the students was the fact that there was insufficient time to complete the task comfortably.
Relating all categories around the core category.	The development activities that took place in the learning environment involved students collaborating with one another in groups using technology to develop an expert system. This facilitated the linking of technology to the learning of communication and provided the students with a novel learning experience. It resulted in a generally positive and enthusiastic attitude toward the learning although some members found the group dynamics frustrating at times. The articulation of the expert system on paper as well as the eventual development of the expert system constituted a representation of their understanding of the content that they were taught. The group collaboration that formed part of the

Table 5.11 Selective coding (continued)

	learning environment resulted in discussion and the generation of divergent and often conflicting ideas. These, together with the hands-on development, often resulted in students thinking at a higher level and in ways that they were unaccustomed to. They indicated that they would be in a better position to apply their learning to different settings as they had obtained a broader insight into the domain. Through this process they seemed to become aware of a higher form of thinking as well as of the complex nature of communication.
Validating those relationships against the data.	Students stated that the environment gave them a “chance to link communication to technology” (FG 4.7.36) and allowed for the incorporation of “technology into your everyday life” (FG 4.1.37) and as a result the learning experience became “enjoyable” (FG 3.3.35), (FG 3.3.36), (FG 4.6.35), “interesting” (FG 4.6.35), (FG 4.1.38), (FG 3.4.4) and even “exciting” (FG 3.4.4), (FG 3.1.11). They also felt that they enjoyed the learning experience because “it was something” (FG 3.1.11) new. A student suggested that it was “interesting because it gives us a challenge” (FG 3.1.5). The students also found the learning method enjoyable and interesting because they felt as though they were gaining "more experience" (FG 2.2.25) to tackle a task that had an authentic feel to it. The focus group interviews revealed that the students felt as though the learning environment gave them a broader, more comprehensive insight into the subject domain. The following quotes indicate an awareness of the "real world" application of communication principles: FG 1.4.5: *Like we learn what our managers out there in the business world expect from us.* FG 3.1.8: *I learnt how to use communication in different situations.* FG 3.1.38: *It is preparing us for our future in workplaces.* The following quotes indicate an awareness of the broad nature of the subject domain: FG 1.8.34: *I can say that I realise that communication is very broad.* FG 1.8.44: *Because communication is broad it is all about understanding and I think all of us we … I mean we found out the other things that we didn’t know.* There was also a sense that the students were encouraged to think about the subject domain in different ways: FG 2.2.17: *It forces you to think outside the box.*

Table 5.11 Selective coding (continued)

	FG 3.1.5: *I find it interesting because it gives me a challenge as a person to think outside the box, not inside.* FG 4.3.3: *I think it helps you think outside the box because you have to think beyond your school days. You have to take your communication level into the workplace.* FG 1.7.9: *I have to think; if it's fine for me; it will be OK or understandable for others.* It was suggested that the students preferred to apply their knowledge by "doing it practically" (FG 2.3.33) as this led to "better understanding" (FG 4.4.19) and that learning became "easier" (FG 4.7.24) when it was "practical" (FG 4.7.24). Some students suggested that it was "easier to remember something that you have done practically" (FG 2.7.34). One student suggested that "even though it [the expert system] does not work at the end of the day" (FG 4.2.14), "the process of creating it", or attempting to create a functional expert system results in learning. There was also a sense among the students that listening to a lecture seems to suggest that the subject domain is reasonably simple, but this is often not the case. The following quotes support this interpretation: FG 4.3.16: *When it is being lectured it becomes easier because we are just looking what you are saying, what you are telling us, we are not applying it. When you start applying it that's where it becomes a problem because we have to do exactly what you have just told us.* FG 4.3.17: *We think its simple but when it comes to applying it, the knowledge, it becomes a problem.* FG 4.4.19: *I think I get a better understanding while practising something, not reading it actually from the book."* Some students suggested that the real thinking took place during the development of the flow-diagram: FG 2.3.21: *I think the only thing that takes time is developing that flow-diagram. Creating the actual expert system doesn't take time."* FG 2.3.21: *But then drawing up that flow-diagram … having to come up with the options and the topic, that's challenging for us."*

Table 5.11 Selective coding (continued)

	FG 2.2.22: *Plotting it down is the problem … when you have to … link.* Many students, however, realised that the development of the functional expert system based on their flow-diagram design was not only time-consuming but also often revealed a breakdown in the logic of their expert system design: FG 4.4.4: *As for us, creating it is more challenging.* FG 4.5.6: *It is difficult because when you draft it on a page it is easier but when it comes to doing it practically it's very difficult because you have to have time and implement all the ideas that you have.* FG 4.7.30: *When you get into a lab, yes, we enjoy it but when we come out we've got to think about what we did and just when we think about what we are doing at the lab we gather the fact that it needs more time like we have to sacrifice some of the time, some of our time. We come into lab late, we do the work and then … yes, but when we get into a lab, its nice and then when you come out we have got to think about what we did there, eish, there we went wrong, there we were right.* The students indicated that the learning experience was often more challenging than they expected it to be: FG 4.1.1: *At first we thought that it would be just something simple, we get into a lab, we do everything, we get done within one hour but as time passed we found it more difficult because it needs more time where a group has to sit down to analyse everything just to get the work done properly.* Students seemed to find the open-ended nature of the assignment disorientating at times: FG 2.2.3: *Communications is really broad; it's like a broad subject, so most of us don't really know where to start.* FG 2.2.2: *The examples you gave us were easy, about the dog or whatever but now we have to create something that has to tell people what to do, which is hard.* FG 4.1.9: *We were trying to do something which talks about Communications whereas we are also learning how to*

Table 5.11 Selective coding (continued)

	communicate. A student suggested that the "struggling" within the learning environment was a positive experience: FG 2.2.32: *I think in the end you will remember this, after all the battling and the crying, you will remember it better than if a lecturer just stands in front of you and actually tells you what to do.* Designing and developing the functional expert system encouraged students to extend their thinking and think at a higher level. One student suggested that “the more you struggle the more you ask questions” (FG 1.3.16). Another student indicated that the learning tasks teach "you to understand the problem before solving it” (FG 4.3.10). It was also suggested that the learning environment encouraged logical thinking: FG 4.6.23: *It makes me become a logical thinker, to think out of the box.* FG 4.2.2: *It needs more logical thinking because when you are doing the program sometimes it becomes more confusing.* FG 2.5.10: *We know the steps and procedures to follow in order to have successful communication.* The discussions and disagreements “make you think more to get like the better idea” (FG 3.5.29) and prompts the student to “come up with different ideas” (FG 3.8.33). This is especially true when there is disagreement within the group and group members need to be “convinced” (FG 3.7.32). Sometimes the disagreements were regarded in a negative light as they "take us back" (FG 3.2.28) and the students "end up arguing" (FG 3.2.28) and "not getting the job done" (FG 3.2.28). There was also concern among various group members that some students were not contributing anything, "not contributing towards the programming" (FG 3.4.21) and "not coming up with any ideas" (FG 3.4.21), and as a result not learning. The group activities also enabled students to combine ideas and "knowledge and compare which one is better" (FG 3.5.36). This often led to a process of discussion where the group "will get the solution that will cover all of them" (FG 3.7.32). The group discussions together with the other planning and development activities allowed the students to gain insight into the broad and complex nature of communication as they were given a "broader mind in understanding what communication is and how to use it" (FG 3.4.4). These activities also enabled students to gain some understanding of how to apply their knowledge and also allowed them to appreciate the complexity of communicating in real world settings as the learning environment takes your "communication level into the workplace" (FG 4.3.3) and encourages you to "think beyond your school days" (FG 4.3.3) and "think outside the box" (FG 4.3.3), (FG 1.6.8), (FG 2.2.17), (FG 3.1.5).

Table 5.11 Selective coding (continued)

Filling in categories (translating them into an analytic story).	Students collaborated in groups to plan and develop an expert system that resulted in a representation of their understanding of certain communication concepts that were introduced to them during the contact sessions. The process of articulating their understanding in this way made them realise that they did not fully comprehend the complex nature of the subject and exposed them to a higher, more comprehensive and sophisticated form of thinking. The flow-diagrams that were drafted on paper and eventually developed into functional expert systems required them to think about communication in broader terms as a variety of possible situations needed to be explored when these activities were undertaken. Students had to consider the value of their expert system to a non-expert user and accordingly were encouraged to contemplate the subject domain from this non-expert user's perspective. The flow-diagrams were mainly in the form of algorithms that required students to trace the logic of the conclusions that were reached when a certain combination of options was selected. This challenged the students to expand their thinking to include logical thinking. The students were motivated to undertake the task of drafting a logical flow-diagram due to the fact that these decision structures were eventually going to be converted into functional expert systems. If there were a breakdown in logic during the paper-based planning stage then this would be carried over to the development stage. The breakdown of logic during the development stage prompted the students to reflect on the logic of their flow-diagrams during subsequent non-computer laboratory contact sessions. This process of reflection facilitated an exploration of the domain that resulted in deeper and broader understanding. The exploration and articulation of various options (contexts, etc.) and the linking of these options to appropriate solutions gave the students insight into the functional aspects of communication as well as to its multi-faceted nature. The group collaboration resulted in vigorous discussion and the generation of differing ideas concerning various aspects of the development. This not only exposed students to different points of view but also encouraged them to defend their own point of view in an attempt to persuade the other group members to adopt a certain course of action. This also seemed to serve as a form of reflection as many of the individual ideas needed to be revisited and modified during this process. These group activities also allowed students to combine and share knowledge, experience and expertise. Comparing ideas, combining knowledge and defending positions encouraged a form of critical thinking. The learning environment proved to be more challenging for the students than they expected it to be. They were more accustomed to attending lectures that were supplemented by conventional study material than being tested on this content. Because this learning environment presented the student with an open-ended assignment that required them to create something original and innovative, students often felt disorientated and out of their depth. They did, however, feel that this feeling of disorientation was mitigated by the group collaboration where students could combine understanding and knowledge, compare ideas and discuss possible solutions to problems. Students were frustrated at times because they felt that they were required to perform a task they did not have the prerequisite knowledge for. They had to think like experts and advise non-experts in a domain that they were not completely familiar with. This prompted them to venture out of their comfort zones and think beyond what they were accustomed to.

Table 5.11 Selective coding (continued)

	The feelings of frustration were aggravated by time constraints. Although they generally considered the software to be easy to use they felt that more practice was required in order to become familiar with the expert system concept and the process of creating one using CourseLab. Some of the limitations of CourseLab as a development environment were exposed due to the students' exposure to other development environments such as Visual Basic. They often felt that it would have been more helpful if they could trace the logic of their expert system by looking at the programming syntax in one view. This is difficult to achieve in CourseLab, which is mainly course development software, as the scripting is done by means of dialogue boxes that hide some of the programming logic from the user.

5.3 Chapter summary

This chapter has presented the findings related to how the students experienced the learning environment based on the conjectures and principles formulated during this research. This presentation involved listing the categories and codes put together through a grounded theory analysis of relevant data. A table outlining the relationships in the data was then presented. This table consists of the following headings:

- Phenomena
- Causal conditions
- Attributes of context
- Other intervening conditions
- Action / interaction strategies
- Consequences of the action / interaction strategies

The central concept or main idea that emerged from the open and axial coding phases of this exploration was then presented and the way in which all other categories relate to this central concept was described. This was done by means of a table that was divided into the following sections:

- Explicating the story line
- Relating categories at the dimensional level
- Relating these categories around the core category

- Validating those relationships against the data
- Filling in categories (translating them into an analytic story)

The following chapter presents a discussion of the findings applicable to this research and an attempt is made to link these findings to the relevant literature.

Chapter 6

Discussion and literature reflection

6.1 Introduction

Chapter 4 presented the data analysis and findings in response to the first research question, namely *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 English Communications students at TUT?* Chapter 5 presented the data analysis and findings that resulted from an exploration of the students' experiences of working within the learning environment developed during the first part of the study.

What follows is a discussion of the findings applicable to this study together with an attempt to link these findings to the relevant literature. This discussion and literature reflection are organised under the following headings:

- Students left to discover information on their own.
- Practical application of understanding.
- Making connections with existing knowledge.
- Collaborating in groups.
- Representing understanding and knowledge.
- Designing a functional expert system.
- Developing a functional application.
- Exploring an ill-structured problem.
- Alleviating cognitive load.

6.2 Students left to discover information on their own

Many of the conjectures and principles formulated during this research involved students being left to discover information and arrive at a conceptual understanding of concepts applicable to the domain largely on their own. A limited amount of measured guidance was regarded as appropriate assistance or support for the learners during this process. This resonates with many ideas reflected in the literature concerning discovery learning and guided discovery learning environments.

In a pure discovery learning environment students are left to figure out solutions to challenges on their own with little or no guidance from an instructor (Prince & Felder 2007, p. 15). Students are principally responsible for finding or discovering the "properties of a domain" when working within a discovery learning environment (Gijlers & De Jong 2005, p. 265). These properties are not made available to the students in a "direct manner" (ibid.). The students are to use interpretation and experimentation to discover them (ibid). The environment provides very little structure within which the learning takes place and the students are encouraged to explore solutions through a trial and error approach (Prince & Felder 2007, p. 15). The idea that students consider their 'mistakes' to be an opportunity to gain an enhanced understanding of communications concepts is a significant component of the conjectures and principles that informed the design of the learning environment. The emphasis is not on correct answers or on definitive representations of understanding, but rather on individual explorations and constructive representation of knowledge. Students are encouraged to learn extra information beyond that which is made available by the lecturer through a challenging process of exploration and discovery. It has, however, been concluded that to allow students to struggle on their own for too long could become demoralising and counterproductive. The conjectures and principles formulated during this study were, therefore, more closely aligned to a guided discovery learning approach rather than to a pure discovery learning one.

In a guided discovery learning environment there is a measured amount of structure and the facilitator offers a calculated amount of guidance to the students (ibid.).

The characteristics, procedures and arguments associated with the principles and conjectures formulated as a result of this research often involved the inclusion of various resources that could be made available to the students during their exploration and discovery of information. Handouts that included terminology as well as step by step instructions and an interactive screen capture demonstration were designed and developed to serve as supporting resources. This is consistent with Veermans, Van Joolingen and De Jong's (2000, p. 233) assertion that support for "discovery learning aims at providing context and tools for performing learning processes essential for discovery learning".

The conjectures and principle formulated in this study presuppose that it is necessary for students to have a certain amount of foundational or fundamental knowledge if they are to function successfully within an environment that requires them to discover information on their own. Prior or existing knowledge has an important influence on knowledge development in a discovery learning process (Gijlers & De Jong 2005, p. 264). In a constructivist discovery learning environment students are encouraged to move away from a passive reception of information toward an active engagement with the subject domain. This could involve the establishment of an extensive application of skills that promote problem-solving and an exploration of unique experience (Castronova 2002, p. 2). These students are also encouraged to build on existing knowledge in order to gain a deeper understanding of information currently being explored (ibid.). New knowledge is constructed by an individual through experiences that allow that individual to "add new concepts to memory, subdivide existing concepts, or make new connections between concepts" (Edelson 2001, p. 358).

6.3 Practical application of understanding

The practical demonstration of understanding is an important aspect of the learning environment designed during this research and many of the principles and conjectures were formulated to facilitate this type of activity. Edelson (ibid.) suggests that being "able to retrieve and recite facts that are relevant to a problem" is of little use if a person is unable to "combine those facts to construct a solution to that problem". The students must learn how to use or operationalise "conceptual knowledge" (ibid.) if the knowledge is to be of any value.

6.4 Making connections with existing knowledge

The principles and conjectures formulated during this research often involved an exploration of the students' existing knowledge before new concepts were introduced. This could be done in the form of brainstorming exercises, paper-based exercises and general student group discussions. The context within which the learning takes place together with making linkages to existing knowledge is alluded to by Edelson (ibid.). He points out that connections that are constructed for subsequent retrieval when learning takes place are dependent on the context in which that learning takes place. The creation and elaboration of these indices or "contextual cues" are a decisive part of the learning process (ibid p. 357). This implies that a learning environment must assist the learner to create suitable "indices to knowledge structures" in order to enable the learner to "retrieve those when they are relevant in the future" (ibid.). Rote learning and the simple regurgitation of facts are characteristic of lower-order thinking while higher-order thinking typically involves combining prior or existing knowledge with new or recently acquired knowledge in order to find solutions to confounding problems (Zoller & Pushkin 2007, p. 155). An exploration of the way in which the students experience the learning environment has revealed that students occasionally found it frustrating to be expected to undertake task for which they felt they did not have the prerequisite knowledge. These feelings of frustration seemed partly the result of being encouraged to think like experts in order to create an expert system.

6.5 Collaborating in groups

Group collaboration is an important aspect of the learning environment designed during this research. Students were encouraged to share understanding and offer support during the exploration and discovery of concepts and information. If students are to investigate a domain within an environment that is based on discovery learning successfully, measures should be in place to support "working in collaborative groups" (Van Joolingen *et al.* 2005, p. 672). This would encourage higher achievement and lead to a deeper exploration of the subject domain. By collaborating in groups students are more likely to engage in a dialogue that contributes to meaningful learning. This dialogue is characterised by the "asking and answering of questions, reasoning and conflict resolution" (ibid. p. 682). The concept *critical thinking* often suggests the comparing and contrasting of ideas, the classification and evaluation of information, and the evaluation of bias (Zoller & Pushkin 2007, p. 157). An exploration of the students' experiences of the learning environment has revealed that collaborating in groups often led to vigorous debate and discussion which in turn resulted in the generation of differing ideas. Students were exposed to various convergent points of view and were encouraged to explore their own ideas more deeply when defending these to the other group members. The dialogue that resulted from group member collaboration also seemed to result in a form of reflection as individual students were often forced to revisit and modify their ideas due to the interaction with fellow group members. The construction of collective or shared knowledge is the decisive objective of collaborative learning. Van Joolingen *et al.* (2005, p. 683) argue that this objective has two important "consequences for the tools in collaborative discovery learning". These are:

- Shared knowledge must be explicitly represented or externalised so that learners can examine the object that is being discussed and explored.
- The tools used should accommodate or allow for the integration of the students' multiple perspectives.

Students typically found the learning environment to be more challenging than they expected it to be and considered the group collaboration to assist in addressing some of these challenges. They were able to share ideas and explore concepts collectively. There were, however, some students who found the group collaboration to be an obstacle to learning as they experienced what they considered to be unnecessary resistance to their ideas and often found that there were students who were not contributing constructively to group activities.

Socio-constructivist learning is based on the idea that learners build an understanding of a subject domain by "working on authentic tasks in realistic settings" (ibid. p. 672). A socio-constructivist learning environment involves peer collaboration and learner-regulated task performance (ibid.).

6.6 Representing understanding and knowledge

An important part of the learning environment is concerned with the externalisation of understanding and knowledge. Many of the principles and conjectures formulated involve characteristics, procedures and arguments that are a factor in enabling learners to represent their understanding by drafting flow diagrams and through the development of a functional expert system. Lee and Nelson (2005, p. 3) propose that complex cognitive processes, such as problem solving, are enhanced and activated through the external representation of knowledge that could make use of symbols and objects. External representations have the potential to be an effective way of addressing complex problems as they help to clarify the fundamental statement of the problem, better its indistinct status to an "explicit condition", limit unnecessary cognitive activity and "generate multiple solutions" (ibid.). Furthermore, an external representation of understanding can be used as a means of clarifying or elaborating and individual's unique "conceptual understanding to others" as well as evaluating the learners' conceptual understanding (ibid.). An exploration of the way in which students experienced the learning environment has revealed that students were encouraged to think about the subject domain in broader terms through the process of representing their understanding. This seemed to be particularly true during the process of drafting an algorithmic flow diagram where the logic behind all conclusions reached needed to be traced and articulated. Any breakdown in logic inherent in the flow diagram is normally uncovered during the development of a functional expert system. This encourages students to, once again, reflect on the logic that was applied to the flow-diagram design and in so doing, explore the subject domain at a deeper level.

6.7 Designing a functional expert system

Closely related to the representation or externalisation of understanding is the idea of designing the functional expert system. This formed an important part of the learning environment and principles and conjectures were formulated to allow for design activities to be incorporated in the learning experience. Contact sessions that did not include computer technology were used as planning and design sessions. Students were encouraged to map out their proposed expert systems using flow diagrams, IF THEN statements and natural language in the form of questions and a selection of answers. The notion of design suggests the creative linking of relationships by collecting information and ideas to form a logical and innovative conception (Kimber, Pillay & Richards 2007, p. 64). The design process involves critical reflection and creative vision and is an important means of "engaging students in knowledge construction" (ibid.). Design activities are suitable for "creating reflective representations of knowledge" and encourage the students to "develop deeper levels of learning" (ibid.). A more coherent and discerning knowledge structure is formulated when the relationship between ideas is articulated (ibid. p. 65).

The results of a study conducted by Kimber, Pillay and Richards (ibid., p. 78) indicate that the activity of design serves not only to apply computer technology "to the manipulation of ideas but also to foster deeper, more critical thinking about content" (ibid.).

6.8 Developing a functional application

The expert system designs formulated in the form of flow-diagrams, IF THEN statements and natural language during the non-computer integrated sessions were converted into functional expert systems during contact sessions in the computer laboratory. This often encouraged the students to revisit the logic of their designs and seemed to allow them to gain a deeper understanding of the concepts incorporated in them. It often became apparent to the students that their expert system designs were not functioning as inference engines that drew conclusions from available facts but were rather designed to aggregate options selected by a potential user. The development activities using CourseLab as an expert system shell facilitated this realisation as it forced them to examine both the reasoning behind the expert system design as well as the utility of the application that they were developing closely. Computer technology that has the capacity to support the creative management and expression of ideas embraces the constructivist position concerning the active building of meaning (ibid., p. 62). Computer technology used in this way enables knowledge to be constructed and reconstructed "progressively, repeatedly and with ease, complementing metacognitive processes visually and electronically" (ibid.). It, therefore, develops into a significant mechanism that supports the "generative learning process" (ibid.).

6.9 Exploring an ill structured problem

An aspect of the learning environment developed during this research involved students engaging with an ill structured open-ended problem. The principles and conjectures formulated regarding problem interaction and problem development revolved around situating the problem in a realistic context, ensuring the emergence of appropriate learning points, providing an appropriate measured amount of guidance and ensuring that the problem statement did not contain an obvious solution. These principles and conjectures resonate notably with many of the characteristics of problem-based learning.

A characteristic of the problem that the students were asked to engage with was that it should be presented to them in the form of a brief rather than a specific scenario with an implied solution. The principles and conjectures regarding problem development clearly indicated that the problem statement should involve more of a conceptual predicament than an exercise that encouraged the students to search for a definitive answer. Problems are distinct from simple exercises in that they require more than simply "knowledge and the application of knowledge" but are conceptual dilemmas that may involve a number of cycles of "interpretation, representation, planning, deciding, execution, evaluation and re-evaluation" (Zoller & Pushkin 2007, p. 155). Jonassen (2011, p. 107) states that ill structured problems "are the kind of problems that are encountered in everyday practice". These problems typically have a variety of possible solutions, imprecisely defined "goals and constraints", "and multiple criteria for evaluating solutions" (ibid.). The productive and meaningful interaction with problems therefore calls for the application of higher-order thinking skills and typically leads to a modified level of understanding rather than merely a resolution to the dilemma (Lyle & Robinson, 2001 p. 443). When endeavouring to "solve ill-structured problems" that lack, by definition, clearly defined solutions "the best evidence of problem solving ability can result from construction of arguments to support the solution that is selected" (Jonassen 2011, p. 107).

As mentioned in section 4.5.4, the principles and conjectures formulated during this research encouraged the students to collaborate in groups in order to explore a solution to the conceptual dilemma presented to them. An investigation into how students experienced the learning environment has revealed that the group work initiated significant debate that often led to the exchange of ideas and the clarification of concepts through a process of comparing and contrasting these ideas. Students were often made to defend their ideas vigorously or attempt to persuade other group members that their ideas were valid. This encouraged them to formulate logically constructed propositions and often led to the amendment of ideas. In a problem-based learning environment students usually work in groups to explore an "ill-structured open-ended real-world" problem (Prince & Felder 2007, p. 15). Students need to use their own resourcefulness to redefine the problem clearly. This involves figuring out "what they need to know and what they need to determine, and how to proceed to determine it" (ibid.). They are encouraged to devise and assess alternative solutions, present a logical argument for the adoption of that solution, and carefully consider the lessons learnt through this evaluation process (ibid.).

The conjectures and principles involved the facilitator being available to offer guidance to students while they were in the process of engaging with the ill structured problem. This guidance should be in the form of guiding questions rather than direct answers. The facilitator should be sensitive to the connotative aspects of the feedback obtained from students and use this to assess the type of guidance that the students may need. The facilitator is responsible for guiding the students toward obtaining information that the students themselves have identified as necessary to a proper engagement with the problem (Prince & Felder 2007, p. 15). Problem-based learning may not be suitable for gaining knowledge quickly but Prince and Felder (ibid) suggest that concepts discovered or constructed in a problem-based learning environment are retained for a longer period of time.

The principles and conjectures formulated during this research place emphasis on designing the problem statement in a way that would allow for the subject domain to be properly investigated. When interacting with a suitable problem, the students will be encouraged to explore appropriate subject content as well as the fundamental principles and concepts associated with the domain (ibid., p. 11). The problem must embody these concepts and engage the student in a process of reflection that leads "to higher-order learning" (ibid.).

A characteristic of the principles and conjectures related to the problem formulation involved situating the problem within a realistic setting that had real world relevance. Hannafin, Land and Olivier (1999, p. 119) use the term *open learning environments* to refer to a learning situation that presents the learner with "complex, meaningful problems that link central concepts to everyday experience" (ibid.). An open learning environment is concerned with examining "higher order concepts, flexible understanding" and allows for a variety of individual perspectives. There is a link between cognitive understanding and context. An open learning environment also stresses the importance of errors during the process of establishing a deeper understanding of concepts and proposes that meaningful learning often evolves from initial, imperfect beliefs (ibid.).

6.10 Alleviating cognitive load

An aspect of the scaffolding provided to the students involves presenting the students with examples of the various concepts explored in the learning environment as well as progressing from simple explanations and instances to more complex ones. This resonated with some of the principles associated with 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). Cognitive load theory focuses on techniques for "managing working memory load" so that information can be passed efficiently onto long-term memory (ibid.). Three types of load are identified in cognitive load theory; these are intrinsic, extraneous and germane. The "number of information elements and their interactivity" determine the intrinsic cognitive load (ibid.). This is the "intrinsic nature of the learning task" itself and it cannot be altered by the type of instructional intervention used (Van Merrienboer & Sweller 2005, p. 150).

Extraneous cognitive load can be altered by instructional intervention as it is comprised of the "load that is not necessary for learning" (ibid.). Extraneous cognitive load is also referred to as ineffective load as it is the product of "information and activities that do not contribute to the process of schema construction" (Paas, Renkl & Sweller 2004, p. 2). Germane cognitive load is considered effective load as it is load that enhances learning as it results in "resources being devoted to schema acquisition and automation" (ibid.).

The conjectures and principles formulated during this research contained characteristics, procedures and arguments that were directed at allowing the students to progress from simple tasks to more complex ones. Examples of flow-diagrams that represent very simple decision structures were initially presented to the students in order to explain the basic symbols used to represent understanding in this way and to introduce them to the logic behind using flow-diagrams. The flow-diagrams became progressively more complex, involving multiple decision structures and partially completed diagrams. By progressing from simple tasks to more complex ones the intrinsic cognitive load associated with a particular undertaking can be reduced. The extraneous aspects of this undertaking can be reduced by initially "providing the substantial scaffolding of worked examples" (ibid., p. 3). These can be followed by "completion problems and then full problems" (ibid.). Paas, Renkl and Sweller (ibid., p. 3) suggest that using worked examples, as an alternative to attempting to solve comparable problems, is a widely accepted and well-known technique aimed at reducing cognitive lead. Jonassen (2011, p. 102) supports this when he proposes that the "most common method for supporting schema construction is the worked example". He goes on to suggest, "It is doubtful that worked examples are effectively applicable to very ill-structured problems" (ibid.). The scaffolding provided by using worked examples can be reduced or faded by successively removing parts of the solution to the problem until eventually only a complete problem or completely unsolved problem remains (Paas, Renkle & Sweller 2003, p. 3).

6.11 Chapter summary

This chapter presented a discussion of the findings applicable to this research and an attempt has been made to link these findings to the relevant literature.

Chapter 7

Summary, conclusion and recommendations

This enquiry followed a design-based research approach in order to design and develop a learning environment that uses computer technology in the form of an expert system shell to facilitate higher-order thinking skills in first year Foundation English Communications Skills students at TUT. Design principles were formulated in the form of conjectures and principles that intended to serve as a guide or reference for those undertaking similar activities under similar circumstances. These conjectures and principles are presented in a descriptive manner and in the form of advice or recommendations that include characteristics, procedures and arguments. Once the design of the learning environment was substantively complete, Foundation English Communication Skills students were exposed to the learning environment based on these conjectures and principles and their experiences related to working within it were explored.

This chapter provides a summary of the problem that gave rise to the research as well as the research design. A summary of the research findings is presented by outlining the conjectures and principles formulated during the design phase of the research and by summing up the findings that resulted from an exploration of the students' experiences. The relevance of these research findings is discussed with particular reference to the South African context. The chapter concludes with recommendations for future research and concluding remarks.

7.1 Summary of the problem that gave rise to the research

A review of the literature (Fisk & Ladd 2005; Stephen, Welman & Jordaan 2004; Thanosoulas 2001; McLaughlin 1999; Bothma, Botha & Le Roux 2004; Jaffer, Ng'ambi & Czerniewics 2007; Scott & Yeld 2008; Legotlo *et al*. 2002; Van der Berg & Louw 2006; Howie 2003; Ngidi & Qwabe 2006 and Schlebush & Thobedi 2004) indicates that many South African students enter higher learning institutions academically under-prepared. This under-preparedness is the result of inadequate schooling. Teachers often seem to have poor content knowledge and interact with learners in a poorly mastered language. This makes the teachers reluctant to engage with the students in a manner that encourages higher-order thinking. These teachers are more inclined to teach answers and, therefore, encourage students to learn by rote. This schooling background often leads students to expect to be provided with solutions to problems without applying any cognitive effort when they enter higher learning institutions.

Computer technology has become an increasingly ubiquitous part of educational environments and is typically used as a medium of instruction. A review of the literature (Jonassen 2006; Hokanson & Hooper 2000; Jonassen & Reeves 1996) however, indicates that computer technology does not perform the role of a teacher very effectively and does not facilitate higher-order thinking when performing this function. When computer technology is used as a cognitive tool to model understanding, however, students are encouraged to engage constructively with the subject domain. Designing an expert system as a cognitive tool requires that students demonstrate or externalise the reasoning of a human expert and encourages them to engage in higher-order thinking.

There seemed to be insufficient understanding of the characteristics of a learning intervention that uses technology in the form of an expert system shell to facilitate higher-order thinking in Foundation English Communications students at TUT. It was within this context that it was considered appropriate to explore the following questions:

- 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 English Communications students at TUT?

- How do foundation students at TUT experience a learning environment 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?

7.2 Outlining the research design

The design of the first part of this study was based on design-research and involved placing a prototype of the design of a learning environment before a design team that was comprised of experienced lecturers and instructional designers. This learning environment was improved and refined through a cyclic process until it was considered substantially ready to be implemented in an authentic, real world educational setting. After each of these design sessions a focus group interview was conducted in order to obtain opinions, ideas and suggestions from the design team. These interviews were recorded and then transcribed verbatim. The modification and refinement of the prototype or tentative learning environment was based on a provisional or formative analysis of the focus group transcripts. A more comprehensive grounded theory analysis of the focus group interview transcripts was conducted in order to discover and formulate design principles. These design principles were expressed in the form of conjectures and principles and followed a format that outlined the characteristics, procedures and arguments allied to these conjectures and principles.

In order to explore how students experienced the implementation of the learning environment designed during the first part of this study, four separate focus group interviews were conducted with a sample randomly drawn from the student population that was exposed to the intervention. The focus group interviews were transcribed and then analysed using the grounded theory technique of coding, sorting and memoing.

7.3 Summary of the conjectures and principles

Conjectures and principles were formulated from a grounded theory analysis of nine of the ten focus group interviews conducted with the design team. Even though the conjectures and principles all concern the characteristics, procedures and arguments associated with the research question discussed in section 7.1 their focus differed at times and can be separated into the following clusters:

- The students' initial exposure to the learning environment.
- The students discovering information and concepts on their own.
- Designing the expert system on paper.
- Creating subject domain awareness in the students.
- Creating an awareness of the relationship between a conceptual understanding and a representation of that understanding.
- The students' hands-on development of a functional expert system.
- The students' engagement with the problem statement.

A summary of these conjectures and principles is now presented by initially describing their more salient features and then an attempt is made to separate these conjectures and principles into their respective characteristics, procedures and arguments by using a table.

7.3.1 Initial exposure

Face to face facilitation supported by a printed handout that contains a step by step guide to developing a functional expert system is characteristic of the students' initial exposure to a learning environment that uses computer technology as a cognitive tool to facilitate higher-order thinking. The face to face facilitation should preferably be the medium used to demonstrate a worked example of a functional expert system. A printed handout that corresponds to the steps used or explained in the demonstration should complement this demonstration. The face to face facilitation would allow any concerns that the students might have to be addressed timeously and it was more practical as it proved to be impossible to anticipate every concern that the students might have if a more static medium of instruction was used. The printed handout would allow the students to follow the demonstration more comprehensively and would serve as a reference when they began the development of an expert system on their own. Table 7.1 provides a summary of the characteristics, arguments and procedures associated with the conjectures and principles concerning the students' initial exposure to the learning environment.

Table 7.1 Summary of conjectures and principles concerning the students' initial exposure to the learning environment

Characteristics	Procedures	Argument
• Face to face facilitation • Printed handout to support face to face facilitation	• Demonstration involving worked examples. • Complemented by a printed handout containing a step by step guide to support understanding.	• Just-in-time support through face to face interaction. • Handouts serve as a supporting instrument to enhance understanding as well as a reference to be used later.

7.3.2 Students discovering concepts for themselves

A number of characteristics that filter through the learning environment developed during this study involve allowing or encouraging students to discover information by themselves. This is achieved by providing them with basic or fundamental information, restricting them to the exploration of concepts in manageable chunks, allowing them to struggle unaided for a limited period of time and encouraging them to consider their mistakes to be part of the learning process. These characteristics resonate with many of the properties of a guided discovery learning environment, which allows for a regulated or balanced amount of assistance from the facilitator and for resources to be made available to the students when they need it. The provision of basic or fundamental information allows for linkages to be made between existing information and new information and helps to prevent students from becoming disorientated and discouraged. Allowing students to struggle on their own for a limited period of time enables them to discover information beyond that which they are being taught and to learn from their mistakes. By monitoring the students' progress, the facilitator is able to prevent the students from encountering an irreconcilable impasse and ensures that the learning objectives are achieved. Table 7.2 provides a summary of the conjectures and principles related to the students discovering concepts on their own by separating these conjectures and principles into their characteristics, procedures and arguments.

Table 7.2 Summary of design principles concerning the students' discovering information on their own

Characteristics	Procedures	Argument
• Students encouraged to discover information on their own.	• Providing students with basic / foundational information. • Allowing students to struggle on their own for a limited period. • Encouraging students to view mistakes as part of the learning process. • Allowing students to explore concepts in manageable chunks. • Monitoring students' progress.	• Build linkages to current knowledge. • Prevent students from becoming discouraged. • Identify when students need assistance.

7.3.3 Designing the expert system on paper

Formulating questions and flowcharts are some of the activities included in the learning environment that involves designing an expert system in order to represent understanding. These activities are preceded by exercises that assist the students in becoming familiar with the flow-diagram symbols and then encouraging them to plot the logic of their expert systems on paper in the form of a flow diagram. This would have the effect of reducing the cognitive load involved in designing the system, as students would not have to be limited or distracted by the challenges involved in using the expert system shell software. This would also give them the opportunity to articulate their understanding of the expertise the expert system is designed to imitate. Table 7.3 provides a summary of the conjectures and principles related to designing the expert system on paper by separating them into their characteristics, procedures and arguments.

Table 7.3 Summary of conjectures and principles concerning the students' designing their expert systems on paper

Characteristics	Procedures	Argument
• Flowchart representation of expert system logic. • Formulation of questions in natural language.	• Familiarise students with flowchart symbols. • Use non-laboratory contact sessions for design. • Encourage students to plot the expert system on paper first.	• Reduces cognitive load. • Articulates understanding of expertise. • Enables students to compare and contrast understanding with group members.

7.3.4 Creating subject domain awareness

The characteristics associated with creating an awareness of the subject domain involve exploring the students' current understanding, paper-based exercises, providing suitable support and using video clips to conceptualise learning. The students' current understanding can be explored through discussion and brainstorming sessions, where the facilitator allows the student group to lead or guide the discussion. Paper-based completion exercises, multiple-choice test items and open-ended questions could also facilitate the exploration of the domain and allow the students to gain insight into various concepts associated with it. Support could be provided by avoiding assumptions regarding the students' understanding and allowing them to ask questions freely. Examples would make concepts less abstract and alleviate the cognitive load associated with conceptual understanding. Video clips depicting realistic communication situations could be used to situate the learning in a realistic or authentic setting. Learning points and conceptual understanding could be rooted in these realistic situations. Paper-based exercises and group discussions could reference these realistic situations to reinforce conceptual understanding. It is, however, important to allow the students to discover concepts themselves and for the facilitator to adopt a more constructivist approach during class discussions. Table 7.4

provides a summary of the conjectures and principles related to creating domain awareness by separating them into their characteristics, procedures and arguments.

Table 7.4 Summary of conjectures and principles concerning creating domain awareness

Characteristics	Procedures	Argument
• Exploration of students' existing knowledge. • Using paper-based exercises. • Providing support. • Using video clips depicting realistic situations.	• Brainstorming, group discussion and paper-based exercises involving multiple choice test items, completion exercises and open-ended questions. • Make use of examples. • Allow students to ask questions freely, clarify concepts and adopt a constructivist approach to allow students to discover learning points on their own. • Showing video clips to students to situate learning in realistic settings that they can reference during discussions.	• Exploring the students' current understanding would allow the facilitator to gain insight into where to pitch explanations and instruction. • Examples would make the learning points less abstract and alleviate cognitive load. • Allowing students to discover learning points on their own would facilitate a deeper understanding of concepts associated with the domain.

7.3.5 Creating an awareness of the relationship between conceptual understanding and a representation of that understanding

The conjectures and principles associated with the representation of understanding involved the following:

- Activities designed to bridge the gap between conceptual understanding and a representation of that understanding.
- Formulating appropriate questions.
- Formulating inferences.
- Modelling understanding through the development of a functional expert system.

To bridge the gap between conceptual understanding and a representation of that understanding seamlessly, a flow-diagram representation of a group discussion involving a communication situation could be drafted immediately after or as the discussion takes place. This would allow the students to view the flow-diagram as an authentic and reliable representation of their understanding and enable them to relate to the logic or utility behind this form of representation. Due to the possibility that the representation of understanding using an algorithmic flow-diagram may place high cognitive demands on the student, owing to unfamiliarity with the flow-diagram symbols and logic, it would be useful initially to draft questions and answers to these questions. These can them be converted into a flow-diagram. The formulation of inferences is an important component of the students' representation of understanding. These inference formulations should be carefully monitored by the facilitator to ensure that they are not merely an aggregation of answers to various questions. An important component of the students' modelling of conceptual understanding involves the development of a functional expert system. This development would encourage them to explore their conceptual understanding of the subject domain more comprehensively. Table 7.5 provides a summary of the conjectures and principles related to the representation of conceptual understanding by separating them into their characteristics, procedures and arguments.

Table 7.5 Summary of conjectures and principles concerning the students' representation of conceptual understanding

Characteristics	Procedures	Argument
• Bridging the gap between conceptual understanding and a representation of that understanding. • Formulating questions and answers. • Formulating inferences. • Developing a functional expert system.	• Creating contiguity between discussion and representations of that discussion. • Encouraging students to formulate questions in order to probe for understanding. • Explaining to students the distinction between the aggregation of options and making inferences based on options selected.	• Contiguity allows students to appreciate the logic involved in representing understanding. • It encourages students to consider the representation to be a true reflection of their understanding. • An inference is a conclusion drawn from available facts and constitutes the display line or the output of the

Table 7.5 Summary of conjectures and principles concerning the students' representation of conceptual understanding (continued)

Characteristics	Procedures	Argument
.		functional expert system.

7.3.6 Students' development of a functional expert system

The students were encouraged to represent their understanding of Communications concepts through the development of a functional expert system. The following characteristics are associated with this component of the learning environment:

- Orientation to the learning environment
- Group collaboration
- Relating the development to the flow-diagram representation
- Becoming familiar with how to use the expert system shell
- The students' active participation in the development process
- Reflecting expert system logic

Face to face facilitation, worked examples and group collaboration are components of the students' orientation to the learning environment that requires them to develop a functional expert system. Face to face facilitation allows the facilitator to provide the students with prompt support. Worked examples lessen the cognitive load by making concepts less abstract and group collaboration allows for peer support and the exchange of ideas. By basing the development of a functional expert system on the flow-diagrams formulated by the students, the students are encouraged to revisit their ideas and conceptual understanding and explore them at a deeper level. Familiarity with the development environment (expert system shell) is important and the facilitator must not assume that the students have sufficient knowledge in this regard. It is important for facilitators to monitor the students' development and to ensure that this development reflects expert system logic by making inferences and not merely aggregating options selected. This can be done by asking questions and allowing students to explain or explicate the logic on which their development is based. Table 7.6 provides a summary of the conjectures and principles related to the development of a functional expert system by separating them into their characteristics, procedures and arguments.

Table 7.6 Summary of design principles concerning the students' development of a functional expert system

Characteristics	Procedures	Argument
• Orientation measures. • Collaborating in groups. • Relating expert system development to flow-diagram representation / design. • Familiarity with the expert system shell. • Active participation. • Reflecting expert system logic.	• Face to face facilitation. • Using worked examples. • Peer collaboration. • Encourage students to base development on flow-diagram design. • Assumptions regarding the students' ability to use the development software must be avoided. • Pose questions to gauge level of understanding.	• Timely response to students' concerns. • Lesson cognitive load. • Peers support one another. • Students are encouraged to explore their understanding more deeply when they revisit flow-diagram design.

7.3.7 Students' engagement with the problem statement

The students' engagement with the problem statement is an important part of the learning environment developed during this study. The following characteristics are associated with the students' engagement with the problem statement that formed part of the learning environment:

- Preferably situated in a real-life or authentic setting.
- Presented to the students in the form of a brief and not a detailed description of a scenario with an obvious or implied solution.
- The ill structured problem must be designed in such a way that allows for the specific concepts to emerge.
- The facilitator must be on hand to provide prompt support.

Presenting the problem statement to the students in the form of a brief that contains a conceptual outline that can be applied to a variety of situations allows the problem to be open-ended in nature. The problem would then accommodate a variety of possible solutions and would give the students the space to explore their understanding at a deeper level. The facilitator must be on hand to provide support but must do so by posing thought-provoking questions rather than imposing his or her own ideas on the student. Table 7.7 provides a summary of the conjectures and principles related to the students' engagement with the problem statement by separating them into their characteristics, procedures and arguments.

Table 7.7 Summary of conjectures and principles concerning the students' engagement with the problem statement

Characteristics	Procedures	Argument
• Situated in a real world / authentic setting. • Formulated in the form of a brief rather than a detailed scenario. • Must not have an obvious solution. • Must be designed to allow learning points to emerge. • The facilitator must be on hand to provide guidance.	• Design in the form of a brief that outlines a concept and not a particular situation. • Concepts should be applicable to an authentic setting. • The facilitator must monitor the students' engagement to ensure that learning points emerge and that they do not reach an irreconcilable impasse. • The facilitator should pose questions to stimulate thinking.	• Allow the students to explore their own understanding and gain a deeper conceptual grasp of subject matter. • The open-ended nature of the problem will allow for multiple solutions. • The facilitator should not impose his ideas on the students.

7.4 Summary of student experiences of 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

Two sets of focus group interviews (four in total) were conducted with the two student groups that were exposed to the learning environment that was based on the conjectures and principles formulated during the design phase of the research. The aim of these focus group interviews was to explore the students' experiences of this environment. What follows is a summary of these experiences as discovered from a grounded theory analysis of transcripts of the focus group interviews.

The exploration of students' experiences of creating flow-diagrams to represent the logic of their proposed expert systems has revealed the following:

- The students were encouraged to think about communication in broader terms.
- They were challenged to think logically about the domain.
- The students were encouraged to reflect on their understanding of the domain when revisiting their flow-diagram design after each development session.
- The articulation of their understanding provided insight into some of the functional aspects of the subject domain.

An exploration of the students' experiences of collaborating in groups within the learning environment formulated as a result of this study revealed the following:

- Group member interaction often resulted in rigorous discussion.
- Group member interaction encouraged the exchange of ideas and exposed students to differing points of view.
- Group member collaboration encouraged students to defend their own points of view, which served as a form of reflection.
- Comparing ideas and defending points of view encouraged critical reflection.
- Group member collaboration allowed students to tackle the ill structured task more successfully.

- Group member interaction occasionally resulted in frustration when it was felt that some group members were being counterproductive or not making a contribution.

The exploration of the students' experiences of learning in an open-ended environment and engaging with an ill structured problem revealed the following:

- Students considered the experience to be more challenging than expected.
- Students sometimes felt bewildered and out of their depth.
- Students often found peer support to be helpful.
- Students sometimes felt that they did not have the required skills to be successful in the environment.
- Students felt that they were required to venture outside their comfort zones and seemed to see this in a positive light.

7.5 Relevance of the study

Scott *et al.* (2007, p. 37) point out that there is unlikely to be a meaningful increase in the number of "well prepared candidates for higher education" in the near future and that progress made in the school sector cannot be confidently relied on to address issues related to the students' under-performance at higher education institutions. Regardless of the limited number of "well-prepared candidates" who enter higher learning institutions, a priority should be placed on realising the "potential and facilitating the successful performance in the existing student intake" (ibid., p. 29). It should, therefore, be one of higher education's main concerns to enhance its own ability to address issues related to the students' under-preparedness (ibid., p. 37). Technology clearly has a role to play in dealing with these concerns. Jaffer *et al.* (2007, p. 141) point out that to improve the typical South African student's potential for success at higher learning institutions a "re-conceptualisation of how educational technologies are applied" is required.

This study presents design principles related to a learning intervention that uses technology as a cognitive tool in the form of an expert system shell in order to develop higher-order thinking skills. The study also offers insight into how students experience a learning environment based on these principles.

The design principles are presented in the form of conjectures and principles that provide suggestions, proposals, assumptions, suppositions and arguments that aim to inform or give substance to a learning environment that endeavours to assist students to acquire higher-order thinking skills with reference to a particular domain. This is particularly relevant to the South African context where students often enter higher learning institutions unable to engage meaningfully with subject matter. The conjectures and principles formulated in this study may serve to facilitate a better understanding of ways in which instructional designers and lecturers can make use of or exploit computer technology to allow or encourage students to engage with subject content in more meaningful ways. This set of conjectures and principles would then function as a model or set of guidelines on which similar endeavours under similar circumstances could be based.

7.6 Significance of the study

Though many of the conjectures and principles formulated during this study are based on a rediscovery of well-established theories and conventions, the context of the study is significant and unique. The problem that motivated the study is the under-preparedness of students for the cognitive demands of higher education and the inability of conventional educational computer technology to address this concern adequately. This study offers a singular insight into a combination of strategies aimed at using computer technology as a cognitive tool to foster higher-order thinking skills in Foundation Communications Skills students at TUT. It also presents a distinctive insight into how these students experienced the learning environment that was based on the conjectures formulated to use technology as a cognitive tool.

7.7 Suggestions for further research

This close and enduring association with and investigation into the use of computer technology as a cognitive tool has uncovered many opportunities for ongoing research. What follows are some suggestions for further research that have become apparent during this study.

- What are the design principles for using computer technology as a cognitive tool in other forms or applications besides expert systems? A few other forms are the following:

    - Mind mapping software
    - Word processing software
    - Data bases
    - Spreadsheets
    - Graphics applications
    - Screen capture applications
    - Web development applications
    - Content management systems
    - Virtual worlds
    - CAD applications

- What are the design principles for combining various types of computer application in order to use them as cognitive tools?
- Formulating design principles that would allow students the freedom to choose the type of application to use as a cognitive tool in a learning environment.
- Using computer technology as a cognitive tool in a learning environment across different domains, for example, Communications Skills and Engineering.
- Identifying the obstacles to using computer technology as a mind tool in an educational environment.

- Formulating design principles for using technology as a cognitive tool over a social network.

Ongoing studies regarding using technology as a cognitive tool to engage students in more meaningful learning could develop from the conjectures and principles formulated in this study.

7.8 Conclusion

This study adopted a design-based research approach to formulate design principles in the form of conjectures and principles related to a learning environment that uses technology as a cognitive tool. What emerged from a grounded theory analysis of the data was not a definitive list of principles but rather a collection of conjectures that could be clustered in certain ways. These were presented in a descriptive format in order to more accurately reflect the essence of the conjectures and principles that emerged from the data. It is hoped that this would provide a useful insight for those who wish to employ educational technology as a cognitive tool to encourage students to explore a subject domain at a higher cognitive level. The study also explored how students experienced a learning environment that was based on the conjectures and principles formulated. This exploration provided an encouraging insight into the value of using technology as a tool that supports the development of understanding and of allowing students the freedom to discover principles for themselves.

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Addendum A Category creation table

Focus group 2

Category	Codes	Quote to support creation of category	Comment
Facilitation Lecturer-student interaction	Face to face facilitation	"I think you should also consider having it facilitated face to face. Rather than working off a printed sheet. Because what happens then, is if you do step by step and they've gotta follow you step by step as soon as there's an issue they you can actually go and address a specific question that they've got." "You might give this to them as a reference for later on. Bit the first time they encounter that you actually facilitate a simple example but on a face to face basis." "… a group of logistics students might struggle to grasp the concept of programming logic, but I think just to support them, give a handout but also maybe go through it step by step in class as well. To pre-empt any problems that they might have." "If you gonna use paper, you gonna end up with quite a hefty manual if you have to predefine everything and give the examples. Even if you explain to them what a variable is, its still not gonna make sense until they see an example."	The initial handouts may have been confusing / to advanced and difficult to follow. There were too many gaps that needed to be filled in through face to face facilitation. Examples needed to be worked through in class, facilitated by the lecturer on a face to face basis. The step by step guide could serve more as a reference then an initial exposure to the expert system shell. Face to face facilitation would be particularly important for students who have not had exposure to programming. There are too many unforeseen issues / problems / occurrences that the students may encounter to anticipate them all in a paper-based tutorial. Face to face facilitation allows you to address these on the fly.

	Step by step guide	"I think just to support them, give a handout but also maybe go through it step by step in class as well. To pre-empt any problems that they might have." "If you regard that this will be the tool to design the expert system in the end. It shouldn't be an obstacle. They should have a handout for reference later on. You explain and then in their own time they can come back and look it up again." " Might help when … you know if they do forget then they've got an assignment and they've got to go and refresh and … what the students do is, they sit in class and they nod seemingly intelligently and understanding, but they don't really, so if you can give them something that they can kinda play with later on."	The sense here is that the step by step guide should serve as a reference for later and should be supported by face to face demonstrations of examples. If they are going to learn to use the software then they will need an understanding of the steps involved to be able to use it appropriately.
	Demonstration	"I would start from the simple and progress. So the demonstration that you do has got to be really the simplest kind of problem that you can give them that will incorporate all the software elements."	This might be the same as 'face to face'. Demonstrations were done using data-projectors. Simplest example that demonstrates all the elements that they are likely to use when they create their own expert systems.

Handouts Composition of handouts	Step by step guide	"I think you should also consider having it facilitated face to face. Rather than working off a printed sheet." "Generally the handout is a good idea, I think. Step by step guide to take them through this" "I think just to support them, give a handout but also maybe go through it step by step in class as well. To pre-empt any problems that they might have." "They should have a handout for reference later on. You explain and then in their own time they can come back and look it up again." "Might help when … you know if they do forget then they've got an assignment and they've got to go and refresh …"	Handout must support other activities like being a refresher for face to face interaction and when undertaking practical exercises. Handout must be composed of a step by step guide that serves to using the software to create an expert system.

	Handout	"... the variety of problems that you will encounter will be quite vast, so to try and cater for everything on a handout is kind of difficult." "… if you gonna use paper, you gonna end up with quite a hefty manual if you have to predefine everything and give the examples." "You might give them this to them as a reference for later on." "A group of logistics students might struggle to grasp the concept of programming logic, bit I think just to support them, give a handout" "…if you test their language proficiency it's not really that good. And then to give them a handout with proper English written on it might not be that useful to them." “I also think there's also the terminology used in the handout, might be an obstacle. You'd need to explain that some" “I also think there's also the terminology used in the handout, might be an obstacle. You'd need to explain that some." "And really simple language and you're going to have to predefine terms all the way."	It would be Impractical to incorporate or anticipate every problem that the student may encounter using a handout. This is one of the reasons why it must only support things like face to face facilitation. The handout might be particularly useful for students who have not had much exposure to a software development environment. Handouts must be written using language and examples that the students can easily understand. It must not be taken for granted that the students will understand all terminology; these need to be explained in the handout. (Predefining terms all the way might clutter the handout and make it too bulky). Handout for reference purposes.

	Handout (continued)	"They should have a handout for reference later on. You explain and then in their own time they can come back and look it up again." “So a bit later, when they've gotta go and figure stuff out, they're not completely lost."	
Scaffolding Providing scaffolding Building in scaffolding	Face to face facilitation	"I think you should also consider having it facilitated face to face. Rather than working off a printed sheet. Because what happens then, is if you do step by step and they've gotta follow you step by step as soon as there's an issue they you can actually go and address a specific question that they've got." "You might give them this to them as a reference for later on. But the first time they encounter that you actually facilitate a simple example but on a face to face basis." “… a group of logistics students might struggle to grasp the concept of programming logic, but I think just to support them, give a handout but also maybe go through it step by step in class as well. To pre-empt any problems that they might have."	Initially there will be too many issues that will be unfamiliar to the students and anticipating these in a handout will be difficult to do. Face to face facilitation will allow the students to have their particular concerns / problems / lack of understanding addressed as it arises. The face to face facilitation is particularly important for students who have not had any exposure to a programming environment.

	Handout	"The variety of problems that you will encounter will be quite vast, so to try and cater for everything on a handout is kind of difficult." "… if you gonna use paper, you gonna end up with quite a hefty manual if you have to predefine everything and give the examples." "You might give them this to them as a reference for later on." "A group of logistics students might struggle to grasp the concept of programming logic, bit I think just to support them, give a handout" "… if you test their language proficiency it's not really that good. And then to give them a handout with proper English written on it might not be that useful to them." "I also think there's also the terminology used in the handout, might be an obstacle. You'd need to explain that some," "I also think there's also the terminology used in the handout might be an obstacle. You'd need to explain that some." "And really simple language and you're going to have to predefine terms all the way." "They should have a handout for reference later on. You explain and then in their own time they can come back and look it up again."	

	Examples	"Even if you explain to them what a variable is, its still not gonna make sense until they see an example." "If you want to use a variable, you gonna have to tell them in simple English what a variable is. With an example."	
	Start simply	"I would start from the simple and progress. So the demonstration that you do has got to be really the simplest kind of problem that you can give them that will incorporate all the software elements. So just to show them what everything means." "… start with a simple problem and then perhaps progress to a bit more complex problem. And the more complex the problem becomes, the more you gonna start kinda focusing on the problem and not as much on the software." "I don't think you should start with a complex ill-defined problem, rather just something simple just so that they can see how the software works and then go from there."	Use simple problem just to illustrate how the software is used. At this point the problem must not get in the way of learning to use the software. As the problems become progressively more complex the focus will shift from learning to use the software to solving the problem
Cognitive challenge	New way of learning	"It is a new way of learning to them. It's not something they're used to."	Because they are not used to this way of learning they might find it more difficult than usual but at the same time the novelty might make them enjoy the challenge more. They may approach it with more diligence.

	Developing something for themselves.	"… they will enjoy developing something for themselves, instead of being given something, as per usual, in the classroom." "… the time when you really start learning the software is when you do something that is meaningful." "But this initial tutorial, I think you'll have to go and follow that up with giving them an actual project to go and do at home or something so they can figure stuff out."	Once again, enjoy because of the novelty but also because of the stimulating process of being hands on. (Applying understanding to something). 'Meaningful' takes the learning from the abstract to something practical, tangible and meaningful. This will enhance the learning. Supplement the tutorial with a practical exercise. The tutorial alone will not suffice; they will not gain a full / meaningful understanding if the tutorial is not supplemented by something practical.

	IT Students Hard for non-IT students	" IT students, that's probably gonna be a good selection, given that they need to work with a little bit of programming logic, because they might be a little bit more familiar with the programming logic than the kind of general student." "Not the IT students as much, but the broader population is going to have difficulty with that." "I think you gonna battle if you work with logistics students, for example." "… a group of logistics students might struggle to grasp the concept of programming logic, bit I think just to support them, give a handout but also maybe go through it step by step in class as well. To pre-empt any problems that they might have."	Leaning the software seemed to be a steep learning curve at this point. Provide the students with a significant cognitive challenge if they had not been exposed to some sort of programming environment before.
	Time		
	Terminology	“I also think there's also the terminology used in the handout, might be an obstacle. You'd need to explain that some." “And really simple language and you're going to have to predefine terms all the way. So if you want to use variable, you gonna have to tell them in simple English what a variable is."	

	Learning to use the software	" .. not a difficult problem because then they're gonna start focusing on the problem. And they gonna get themselves lost in the problem and not focus on the software kinda thing." "I don't think you should start with a complex ill-defined problem, rather just something simple just so that they can see how the software works and then go from there."	

Focus group 3

Category	Codes	Quote to support creation of category	Comment
Scaffolding Providing scaffolding Properties: •	Battle on your own	"… battling a bit on your own is a good one from a certain stage on. I think that if you just go and dive in and you start to figure it out, that might just become a bit demoralising. "So, to a limited extent, let them try stuff on their own for a while. For a brief while. Not too long. And then show them the right way. So that they not only learn what you teach them in class, but also that little bit extra that they discover."	Allowing or encouraging students to battle on their own is only constructive / beneficial from a certain stage in the learning process. It would be counterproductive to compel them to work completely on their own to soon in the learning process. (could relate this to the 'Build on basic knowledge' code). Students should not be left to struggle on their own for too long before the facilitator intervenes and provides them with guidance. This will allow them not only to learn from the guidance provided by the facilitator but from the process of self-discovery.

	Break into bits	"What I think you could do to get around the speed issue, is to do something, and then stop and make them do it. Not to just let them watch through the whole presentation and then the first thing they're gonna forget again." "I really think the screen freeze is very good to use. Once you've done a step just to freeze the screen and then give a little written explanation of what you've just done."	'Speed', maybe 'pacing' or learning content more efficiently. Breaking material into small chunks allows the student to assimilate material more effectively. A long, uninterrupted presentation may result in excessive cognitive load. Presenting material using a 'screen freeze' method may be an effective way of breaking it into manageable chunks.
	Decrease in the scaffolding	"You did kind of decrease in the scaffolding quite good today kind of thing. In the same way the first one, step by step, do or show something and let them do it. Then the second one you kind of step back a little bit and you ask them, okay, what must we do next and then they must do it. Then you say, okay, do this now on your own."	Decreased scaffolding: 1) Step by step demonstration. 2) Ask class to tell what comes next. 3) Do it on their own
	Direct interaction	"What I found very useful when you demonstrated is that I had the opportunity to directly ask you a question, immediately, when I didn't understand what was going on. Whilst if I did it on my own, I would maybe have forgotten, but the direct interaction is good." "The show and tell, and then the ‘do’. If that works together and you are there to assist and give direct feedback."	Students could ask questions as soon as they encounter difficulties. This 'direct interaction' allowed them to pose their question to the facilitator before they had forgotten the problem that was encountered. (Interactional support)

	Examples (Worked examples)	"You made us work through examples which showed us which question would work and what would not work. For the result we wanted in the end …" "… if you go and you do basic example and then you give them something that they have to try and figure out on their own, and you give them a while to play with that."	The reduction of extraneous cognitive load through the use of worked examples.
	First put things on paper	"What worked for me is to first put things on paper. Like generally works for me in any event. You write things out and see how it works out there and then from there on you show us the tutorial." "If they can do it here on paper, then it should be easier for them to transfer it when they see what they are doing and then they can do it themselves on the computer." "… you've broken it down into logical bits which follow on each other. First the paper-based, then working on your own, then you demonstrating and I could apply what I learnt and I could see the logic behind what you were doing there because I knew what the symbols stood for."	Plot the logic of the expert system in an algorithmic flow-diagram. Could this have something to do with cognitive load? (I.e. battling with learning the software interferes with the grasping of the logic of the expert system design). Plotting it on paper reduces the cognitive load because once you are familiar with the flow-diagram symbols; you can concentrate on the logic of the expert system and not on how to use the development software.
	Screen capture	"Screen print that you demonstrated will be very useful. Where you break down into a capture of the logical steps." "… as you went through it now, it was a bit quick and if you did it in that way, it would've been easier to follow." “I really think the screen freeze is very good to use. Once you’ve done a step just to freeze	A screen capture of the steps involved in developing an expert system based on a 'worked example'. The demonstration 'freezes' at logical (salient) points during the development, students can interact with the demonstration and 'start' it again once they feel they are ready.

		the screen and then give a little written explanation of what you've just done."	
	Sequence	"First the paper-based then working on your own, then you demonstrating and I could apply what I learnt and I could see the logic behind what you were doing there because I knew what the symbols stood for. You made us work through examples which showed us with question would work and what would not work." "… battling a bit on your own is a good one from a certain stage on. I think that if you just go and dive in and you start to figure it out, that might just become a bit demoralising." "… first put things on paper. Like generally works for me in any event. You write things out and see how it works out there and then from there on you show us the tutorial. If it makes sense then, I think after that then the students must do it themselves."	1) paper-based. 2) Facilitator demonstrated. 3) Apply learning (could now understand logic behind what was being done). Can't allow students to battle on their own too soon. Must be done at a certain stage in the learning process. Start simply or in a way that is more familiar, more comfortable. First principles: (a) activation of prior experience,(b) demonstration of skills (c) application of skills and (d) integration of these skills into real-world activities.
	Pace (Slow pace)	"… your pace must be slow. Especially if you go through the functions and make sure that they all see it and also that a guideline needs to be there; it needs to be double-checked on this."	Pace must be appropriate to the complexity of what is being demonstrated and the ability of the students. Supported by a step by step handout that can be referred back to.
	Start simple	"I think after that then the students must do it themselves, but I think the main thing is to start with a simple one like here in the beginning when it's only two options so that they can work it out."	This is directly related to intrinsic cognitive load. Intrinsically the concepts involves are too complex to be accommodated in working memory

		"I think for the first class, just do the basics first, and one question, and a simple algorithm and then build on that further." "First get the basics under control and then carry on with the more involved things."	all at once; simple versions have to be presented to the students so that schemata are created in long-term memory. These schemata are then brought back into working memory when the complexity of the concept needs to be understood. Flow-diagram with only one or two options in order to reduce complexity.
	Step-by -step	"In the same way the first one, step by step, do or show something and let them do it. Then the second one you kind of step back a little bit and you ask them, okay, what must we do next and then they must do it. Then you say, okay, do this now on your own." "But you can like probably break this down into about 3 or 6 stop- starts, where you do something and you say, okay now it's your turn. You go and build it." "So if they can, after each step just do it and then they should be fine."	Again this seems to be related to intrinsic cognitive load. After each step (logical step) the students consolidate their understanding by applying something; this may assist in the creation of schemata in the long-term memory.
Discovery learning Properties: • Active learning • Meaningful learning	Build on basic knowledge	"… as your foundational knowledge increases, it's easier for you to relate new stuff to it. So if you play around without having any foundational knowledge there's nothing to make linkages to. But as you build on the foundational knowledge, it becomes easier to make new linkages to it."	In discovery learning students are encouraged to undertake activities that build on existing or foundational knowledge (Castronova, 2002:2)
	Trial and error	"But I also think that trial and error is very important because last time I sat and I got stuck at a certain point and once you have gone through the whole process slowly, it	Discovery learning does not place significant importance on correct answers and considers failure as a constructive part of the learning

		makes sense now, but just to find the correct pitch between trial and error and doing it by themselves and giving them the information that will be tricky, I think. To find the correct balance between doing it on their own and providing them with information."	process (Castronova, 2002:2). Discovery learning incorporated within guided learning strategies where the facilitator establishes some sort of balance between letting the students find their own way and guiding them toward a desired outcome.
	Apply learning	"First the paper base, then working on your own, then you demonstrating and I could apply what I learnt and I could see the logic behind what you were doing there because I knew what the symbols stood for. You made us work through examples which showed us which question would work and what would not work."	Emphasis on active participation or construction of understanding.
	Battling on your own	"… battling a bit on your own is a good one from a certain stage on. I think that if you just go and dive in and you start to figure it out, that might just become a bit demoralising." "… what happens in the process of fiddling is you then discover other things which don't answer your question now but stays in the back of your mind for later on when you've got the question that needs this answer. So, to a limited extent, let them try stuff on their own for a while. For a brief while. Not too long. And then show them the right way. So that they not only learn what you teach them in class, but also that little bit extra that they discover."	Guided discovery learning. Facilitator must provide appropriate guidance during the discovery learning process.
	Sequence	"… first put things on paper. Like generally works for me in any event. You write things out and see how it works out there and then from there on you show us the tutorial. If it makes sense then, I think after that then the students	Explore the structure of a discovery learning environment.

		must do it themselves." "… battling a bit on your own is a good one from a certain stage on. I think that if you just go and dive in and you start to figure it out, that might just become a bit demoralising." " I think after that then the students must do it themselves, but I think the main thing is to start with a simple one like here in the beginning when it's only two options so that they can work it out." "I think for the first class, just do the basics first, and one question, and a simple algorithm and then build on that further."	
	Hands on	"What I think you could do to get around the speed issue, is to do something, and then stop and make them do it. Not to just let them watch through the whole presentation and then the first think they're gonna forget again." "But you can like probably break this down into about 3 or 6 stop-starts, where you do something and you say, okay now it's your turn. You go and build it." "I think if you provide them with too much information, then and without them doing it on their own, they will also feel lost." " … if you go and you do basic example and then you give them something that they have to try and figure out on their own, and you give them a while to play with that.". "… the better they get at using the software,	Active participation is a property of a discovery learning environment.

		the better they get at discovering stuff by play around." "So if they can, after each step just do it and then they should be fine."	

Focus group 4

Category	Codes	Quote to support creation of category	Comment
Domain appreciation Subject awareness	Brainstorming Explore students' understanding (this could be a category)	"… maybe have a brainstorming session about different communication contexts in little groups, umm, but just to create the context of what to expect in the class and then getting feedback from all the groups I think that then you already have something to work with …" "… instead of just explaining everything ask them what their understanding is of the concepts before you start. And then break it up."	Brainstorming or exploring the classes or various groups within the class's current understanding of various communications concepts may provide the facilitator with an insight into the general level of understanding within the class (base level understanding) Give the facilitator an insight into where to pitch lessons and not to make unrealistic (baseless) assumptions. Brainstorming sessions may also create awareness within the students of various communication contexts and concepts.
	Clarify domain concepts	"We spoke earlier about your need to explain what the different components actually mean if you talk about *context* what do you mean, if you talk about *audience* what do you mean by *audience,* so perhaps just remember when you get to the section of the questionnaire that deals with context that you just step back a little bit and explain exactly what you mean by context and when you get to audience just	Paper-based exercises should be supported by other activities that explain and clarify various domain specific concepts. It should not be assumed that students have a foundational understanding of the subject.

	Avoid making assumptions	explain a little bit further." "Terminology like the word *context*, like the word *situations*, things like that. The assumption is maybe that they would know what it means, but I don't think we can make that assumption."	
	Example	"…give them an example maybe of the communication situation if you want to, I know you said that you didn't, but make it something different then the context that you have there, like a corporate environment, make it something different that they can't use. That will give them an idea of along which lines they should think." "You can give them scenarios as example; you don't have to say this is exactly how I want it but it gives them a cleared direction of what is expected from them, umm, I mean it helps to give them more guidelines, I mean you don't have to give them the recipe, they have to figure out the recipe for themselves here."	Providing examples may be an effective way of making the Communications concepts less abstract. The concern, however, is that the example may simply be regurgitated when students are left to explore the concepts on their own. It may inhibit (interfere with) the discovery learning process. The examples need to be designed in such away that this situation is averted. The examples / scenarios should serve as guidelines without directing the students too definitely. Not giving them the 'recipe'? Could the examples be in the form of problems without exact solutions, almost like ill structured examples?
	Must know where to start	"I know you want them to struggle but they should have an idea of where to start otherwise they might not know what to do." "They know what you want to achieve; instead of you tell them what you want them to achieve at the end they have to bring in their input, they have to trust in their creativity that they are going to create something that hasn't been	When exploring or embarking on a discovery learning process, students will be disorientated if they are not giving sufficient guidance. The need to be given some sort of direction to start from. Similar to building on foundational knowledge.

		before. You know something like that. For me it's a bit more guiding, and then when you come to this part where they have to develop the flow-diagram the moment that they get their beginning must be clear otherwise they will not be able to do this."	The starting point must be apparent to the students otherwise they will feel disorientated. Examples, scenarios should form part of this orientation process.
	Face to face	"I think that the questions could just be more specific and if you have a forum where you have face to face interaction with the students while they work that terminology should be explained and that feedback should be given after each logical gap."	Immediate feedback from the facilitator could provide the support necessary when students work through paper-based exercises.
	Handouts	"I think the fact that you gave us paper-based questions so that we had something in front of us to work with was a good idea."	The paper-based exercises served to facilitate group discussion and an exploration of various communication concepts and situations.

Focus group 5

Category	Codes	Quote to support creation of category	Comment
Representing a conceptual understanding	Bridge the gap	"Well the way that you demonstrated it here facilitating, sort of another brainstorming session but not doing a mind map, doing the flowchart immediately. That would bridge the gap for me back again to the flowchart and show me what would be the end product, that you would expect from me, without telling me what to do and what to put in specifically. " And then if you guide that discussion towards, let's say product as a concept, you start talking about you know what's on the board there what … you know discuss about, without telling people that they are discussing product, you just start leading some kind of	Lesson outline (this was done during the following lesson): **Step 1** Brainstorm with class to explore understanding of Communications concepts. **Step 2** Divide class into groups, send all but one group out of the class and show that group a video clip of a communication situation. **Step 3** Invite the other groups back into the class and ask them to determine what the context was in the video clip by posing questions to the group that remained in the class. Record

		discussion on what the product is. And once they have discussed that a little bit and explored and got them to what you really want them to understand about product then you can step back and summarize for them." "That is a good way of them kind of analysing the situation first and then reducing all that discussion down into a formation of a concept."	these questions using a white board or data projector. **Step 4** Repeat with other groups **Step 5** Consolidate the questions through class discussion. **Step 6** Demonstrate to the class how these questions and answers can be represented using a flow-diagram and IF THEN statements. The flow from creating or gaining an awareness of various Communications concepts, to formulating questions to probe or explore these concepts with reference to authentic examples and then to represent these insights immediately using a flow-diagram could create a seamless transition from conceptual understanding to a representation of this conceptual understanding. The relationship between an understanding rooted in a specific instance and a more abstract representation of this understanding is made evident by immediately transferring the group's reasoning onto a flow-diagram. There was a seamless progression from analysing an authentic example to representing a conceptual understanding that resulted from this analysis to a flow-diagram that could then form the basis of a functioning expert system. Without this immediacy

			the students may find it difficult to bridge the gap between a conceptual understanding and a representation of this understanding. By allowing an unscripted class discussion to developed or be transformed into a flow-diagram that can then be converted into a functioning expert system may encourage students to consider the process to be an authentic or accurate reflection of their understanding. They may, consequently, be encouraged to recognise this representation as a true expression of their socially constructed experience.
	Contiguity	"… if you could do a video clip and have them discuss a concept, like purpose for example, and then once you have summarised and told them this is what purpose is about and then move directly onto flowcharting purpose, then it keeps everything together and it actually gives them a good understanding of what it is when you talk about a flowchart what it is that you are trying to achieve from them. So I think what you did there was quite a good way of doing that."	The contiguity of the discussion of the concept and the representation of the concept using a flow-diagram enables the student to understand the logic behind using a flow-diagram to represent their understanding. It creates a more concrete or obvious link between the concept and its representation.
	Flow-diagram	"Do this and then go on to do maybe one example of their own, there own scenario. Exactly like last week but maybe one scenario. Because then they will know what it's all about and then move on to their own flow-diagram. That can work the two exercises together."	Once they have understood or appreciated the link between a conceptual understanding and a representation of this understanding they can proceed to represent a scenario informed or

		"It worked well for me, the flowchart immediately." "I think that it links nicely, theory with practice, the flowchart. Because now they did the theory, all these concepts and now they must just represent it practically in an expert system, and, umm, I think this provides a good link between the theory and the practice."	inspired by their own experience using a flow-diagram. This could be the other way round. The practice could be seen to be represented in the video clips and the theory could be seen to be represented by the flow-diagram. Perhaps the flow-diagram could be considered to be a concrete or hands-on representation of a theoretical understanding?
	Representing understanding (alternative)	"… depending on the need of the student or maybe his way of expression that they can either do the flowchart or then write it out in natural language which … it could be a preference … you can give them the opportunity to choose between the two, ummm, and there might be somebody that is most comfortable with doing the flowchart and then writing it out so before he gets to the expert system then he knows that there is nothing in-between that I left out." "For the purpose of them understanding of the concept it might not be the best way for them to understanding the concept. So that's why I say the flowchart might obscure their understanding but then again I've got my lecturer hat on and thinking about what's going to make the students understand best."	Representing conceptual understanding using a flow-diagram should not present the students with an unnecessary learning curve. They may feel more comfortable using natural language to represent this understanding. Some students may not find representing their understanding in this way to be helpful. These students may prefer to use 'natural language' to do so.
Facilitating a conceptual understanding of the domain	Domain knowledge	"… What we missed last time was the step in-between and this lesson was the step in-between. From the beginning when you explained the expert systems and then the CMAPP … so it was very good and. giving	The exercises were not as open-ended but contained multiple-choice questions related to a video clip that they were shown. This seemed to facilitate a better

		some … something more sound that's not completely abstract so I think it's a good idea." "… you can use different video clips to do that, you; can use one video clip for product and one video clip for purpose for example So you take the next video clip an you start discussing the purpose without telling them that that's what you are doing and you take a step back and you summarise and you say OK, in that video clip this was the purpose so that they understand these things that they had running around in their minds now, that that goes to purpose." "That's a good way of them kind of analysing the situation first and then reducing all that discussion down into a formation of a concept."	understanding of the domain and related an understanding of the domain to the expert system concept and logic. Using different video clips, the facilitator can focus on different communications concepts. Each video clip must highlight or enable a discussion on a discrete communications concept. These concepts must emerge naturally, which may involve the facilitator selecting video clips with the different learning points in mind (Bearing in mind the different learning points when selecting a video clip). This would facilitate and analysis of various communications situations and then the formation of concepts.
	Example Scenario	" I like that you take context and you work through an example in detail, like we did today and you go back to the video clips and we start discussing some stuff in the video lips." "… modelling their own diagram based on their own scenario, like last weeks exercise perhaps. It would work well after you have done that example. And they are still not going to model what you have done there; they will still have to think about it themselves." "… maybe we should swop the two exercises from last week and this week. Do this and then	The discussion of the various communications concepts is rooted or grounded in a realistic situation or a practical demonstration. This realistic situation can be referenced in order to allow learning points to emerge or conceptual understanding to take place. Once they have developed a model of their understanding of various communications principles that emerged as a result of

		go on to do maybe one example of their own, their own scenario. Exactly like last week but maybe one scenario. Because then they will know what it's all about and then move on to their own flow-diagram. That can work, the two exercises together."	watching video clips, the students may be ready to formulate their own scenarios and develop models related to these. (This was tried in the week previous and considered to be to difficult and disorientating)
	Handouts Scaffolding	"I also like the paper-based exercise because scaffolding was provided by first starting with multiple choice, just opinions and then later they had to express themselves in writing and then in paragraph form as well. So I think that it was well structured and scaffolded and also visually"	Initially the handouts were considered to be too complex because of their open-ended nature. Scaffolding in the paper-based exercises by giving the students multiple-choice options from which they could choose and answer. It was only subsequent exercises that were more open ended in nature (Choose options that related to the video clip). Progress from guided options (multiple-choice) to open ended, where they even formulate their own scenarios.
	Video clips	"The segmented way that we did this and the video clips the visual really I think will draw in the students and the real-life situations, the complex real-life situations would help them a lot." " I like that you take context and you work through an example in detail, like we did today and you go back to the video clips and we start discussing some stuff in the video lips." "… you can use different video clips to do that, you can use one video clip for product and one video clip for purpose for example So you take the next video clip an you start discussing the	The video clips may help to situate the learning in a real world context and make the students appreciate the relevance of the learning. Give them an insight into the complex nature of communication in a real life situation. The video clips serve as a useful reference that may reinforce a conceptual understanding (Ground the learning). Video clips can be selected specifically to highlight certain

		purpose without telling them that that's what you are doing and you take a step back and you summarise and you say ok in that video clip this was the purpose so that they understand these things that they had running around in their minds now, that that goes to purpose." "…the students will have real visual interaction with the videos that you are going to show and based on the videos they can answer these questions." "… The visual clips were very interesting, that's always interesting to students to have something like that and not everything paper-based. So I think that will be a good starting point or point of departure for the students." "… when you do the t paper-based exercise, to do a clip and then make them answer the questions on it, do a clip and make them answer the questions on it. Because it keeps the content of the video fresh in their minds as well while they are busy do that."	communications concepts. Might allow for a discrete separation of the various communication concepts. Perhaps some of the clips may have certain of the concepts as more prominent but the others are still there (the other concepts can be pointed out in the clip once an overall conceptual understanding has been gained).
Guiding / directing domain analysis (Scaffolding)	Class discussion	"And then if you guide that discussion towards, let's say product as a concept, you start talking about you know what's on the board there what ... you know discuss about, without telling people that they are discussing product, you just start leading some kind of discussion on what the product is. And once they have discussed that a little bit and explored and got them to what you really want them to understand about product then you can step back and summarise for them."	The face to face discussions concerning the domain must be allowed to develop spontaneously. The learning points should emerge naturally and then made more apparent to the learners during a consolidation and summarising phase.

	Face-to face	"I think the face to face interaction worked very well. I think the way that we progressed with facilitation through the concepts worked very well." "I wouldn't go and give them more paper work, I would go … do the basic concepts that you did multiple choice questions etc and then do the rest segmented, umm, with all the other concepts face to face based on the video clips again."	The integrating of face to face facilitation, paper-based exercises and the viewing of video clips depicting realistic situations must be carefully managed. The paper-based exercises can be used to introduce basic concepts to the students. This may make the viewing of the video clips more meaningful to the students and lead to more constructive class discussions. The face-to face facilitation allows concepts to emerge spontaneously during class discussion.
	Feedback	"This worked well because there was a lot of feedback and discussion.	Obtaining feedback from the class is important if concepts are to emerge spontaneously.
	Real-life situations	"The segmented way that we did this and the video clips the visual really I think will draw in the students and the real-life situations, the complex real-life situations would help them a lot."	The real-life situations depicted in the video clips would help make the concepts less abstract for the students.
	Segments	"The segmented way that we did this and the video clips the visual really I think will draw in the students and the real life situations, the complex real life situations would help them a lot." "I wouldn't go and give them more paper work, I would go … do the basic concepts that you did multiple choice questions etc. and then do the rest segmented, umm, with all the other concepts face to face based on the video clips again."	Breaking a complex situation into sections to facilitate analysis. Use the paper-based exercises to supplement the face to face interaction. The learning environment must be structured around face to face interaction at this stage. Going through the learning concepts in stages, referring back

		"I like that you take context and you work through an example in detail, like we did today and you go back to the video clips and we start discussing some stuff in the video lips." "… when you do the this paper-based exercise, to do a clip and then make them answer the questions on it, do a clip and make them answer the questions on it. Because it keeps the content of the video fresh in their minds as well while they are busy do that."	to the video clips to underline and reinforce learning. Referring back to the video clips to initiate discussion once the students have gained some insight into the concepts. It is advisable that there to be close contiguity between the viewing of the video clips and the discussion that aims to facilitate the emergence of learning points.

Focus group 6

Category	Codes	Quote to support creation of category	Comment
Scaffold thought process / scaffolding flowchart construction	Bridge the gap	"I think you bridged the gap very well today, jumping from the conceptual learning to physical manifestation in the flowchart. For me today there wasn't that moment of hesitation of what should I do next, it flowed naturally and that worked well." "The idea behind today was to bridge the gap between a conceptual understanding and a representation of that understanding. How do I improve this?" "It was natural for me … when you had the questions … remember they have seen all of this … asking the questions and they know what those shapes mean now so now when you put the question there then obviously they have to think of all the different settings for example and then take one and what's	The lesson facilitated the seamless progression from a conceptual understanding to an articulation or representation of this understanding in the form of a flow-diagram. The development or formulation of the questions helped to make the construction of the flow-diagram seem natural. The formulation of the questions developed naturally from the class discussion / activity. This separation of question formulation and flow-diagram construction may relieve the intrinsic cognitive load associated with putting together a flow-

		involved there, that is logical to me." "…here were things that you had to think about but because you already had those questions it just made that gap more digestible and easier to work with." "…in one of the previous sessions, where we had to make that jump, I had to readjust my mind and ok now we are going to the flowchart, what now. What question is first? What should happen now? And with the questions already developed today, you could basically just apply it to the flowchart and there were not so many things that you had to consider so that it wasn't as daunting a task."	diagram that represents the student's conceptual understanding of various communications concepts. Intrinsic cognitive load is reduced by allowing for the development of the questions before the drafting of the flow-diagram. The logic of the questions is applied to the drafting of the flow-diagram.
	Flow-diagram	"… nice I think way of getting to the logical way of flowcharting something like context … It was a nifty idea to do it this way round, I think it might work well." "… What you are doing is you are going through the thought process that they need to follow to get to the questions that they need to ask to get to the flowchart without them knowing that that's what they are busy doing." "I think you bridged the gap very well today, jumping from the conceptual learning to physical manifestation in the flowchart. For me today there wasn't that moment of hesitation of what should I do next, it flowed naturally and that worked well." "…why did it work well? "Umm I think it was a natural progression into	Guiding students through the thought process that needs to be followed to draft a flow-diagram that articulates the logic of an expert system. Formulate questions that can be asked to explore various communications concepts embedded realistic communications situations. Using these questions to construct an algorithmic flow-diagram. The subtle guidance will allow the students to see the process as less contrived and artificial. This may help them appreciate the relevance and serve as a source of motivation. The subtle natural guidance prevents students from wondering what the learning agenda might

		… because you have already now drafted the questions and you don't have to now go sit and think, if I do this flowchart now what would be the best question to ask, what would … to develop questions, because now the questions are there already." "Because that, umm, will tell them that the order of the questions … now this is difficult because as you said sometimes some questions do lead on to the other, umm, but unless that is like really really apparent from the questions that you would need to ask this question first. If there are five questions and they are all equally important, it doesn't realty matter where you start, I would ask them where do you want to start from so that they understand that they can start from any place and the way in which they do it is not going to be incorrect if you start doing it at a different place." "… that thing about, that there are many different ways of representing that because your learners … especially if they are like younger learners they are going to want to copy what you are doing. So if you don't make that very clear you are gong to see all of your flowcharts looking like this and you ... I don't have to tell you that." "… here is really where the learning is going to start taking place, when we send them back in their groups to go and develop a flowchart on their own."	be. Natural progression from general class discussion to a realisation of the logic of an algorithmic flow-diagram. The natural progression may serve to prevent excessive cognitive load. It is advisable for the facilitator to adopt a flexible approach. Must be guided by the response or feedback obtained from the class. Try and accept the students are responsible for guiding the learning outcome and the formulation of the questions, etc.

	Group work Practical application	"I think that it is important to, from here on, to take that … to give it to groups to do some work on their own, to really get to grips with what this process is."	Class discussion and then guided facilitation of flow-diagram development must be followed by a practical application of understanding.
	Logical	"It's logical also because we have that background and you have done that in the beginning, showing how this chart works, that was good. If you haven't done that and you get this, now then I would have been lost …"	Preceding steps make the process logical, an understanding of flow-diagram symbols, expert system logic.
	Real life	"I think using the newspapers, using the clips, the real-life environment; I think that worked very well. It's not something separated from what they do everyday, they see that this is real life, this is how it is and they can work through this. It's not a separate concept that they have to grasp."	Situating the learning within authentic or realistic settings may make the learning more relevant to the students. The learning is situated within settings that the students are better able to relate to.
Facilitator responsiveness / awareness	Constructivist facilitation	"Your facilitators need to be trained for constructivist interaction. That's not something that comes natural." "… first thing that he needed to do was to actually train the facilitators how to facilitate a constructivist learning environment. That's not something that they learn naturally." "Naturally you want to stand here and you want to lecture down to people. So you need to get used to this constructivist environment where the learning belongs to you constructors, not to your facilitator. And when you have a dead spot you need to trust that dead spot, you need to know that that's part of the process you know and how to facilitate through that perhaps. But ,umm, if these guys aren't trained and they walk in there and they encounter a dead spot the natural reaction is	It is advisable to allow the learning points to emerge naturally from the class discussions. The questions that are formulated must emerge from the class discussion. No question must be added to the list that has not emerged naturally from the class discussion. The facilitator must not impose a question on the class, all questions must emerge naturally. Facilitators must be sensitive to the fact that the learners must direct the learning outcomes. The class activities must be facilitated in such a way that the learners feel comfortable to freely make contributions. They must be guided not to expect to be

		to start lecturing, umm, so they need to be trained on how to facilitate in that kind of environment." "… you ask them the first question and nobody answers you and you wait for a while and there is this unnatural pause and then you start talking and there you have lost the plot. That's something that they need to learn how to do and once that happens … that's just the first. Now you've got a group of learners who've never really worked in that way, so they need to become familiar with a constructivist learning environment, they need to overcome their natural resistance to speaking up in a group and to participate because you cant construct knowledge, especially in a social constructivist paradigm, you cant derive group meaning if nobody is speaking. So you need to do some training beforehand before this is going to work."	provided with answers or solutions by the facilitator. The facilitator must probe for contributions and resist a natural tendency to fall back on conventional lecturing techniques. It is advisable for the students to recognise the questions and flow-diagrams to be an authentic representation of their understanding or cognitive conceptualisation.
	Facilitation	"I also agree with them about the facilitators and maybe your first class or the first thing, when they introduce it you should maybe there just to check that they know what is going on and they are doing what they are supposed to do. Otherwise you are going to, umm, leave it all in their hands and then in the end maybe get some feedback or information that this is not quite what you were hoping for." "… because that's where they are going to start negotiating amongst themselves to get a flowchart on the ground. So I think that's really where the understanding is going to start, when they start interacting with each other and in that process I think the first couple of times,	Importance of correct or suitable facilitation. Facilitators must be in tune (sensitive to) with the feedback elicited from students. Must be prepared to make adjustments and amendments to learning environment and interaction. Responsive to feedback obtained from the class. The students' understanding is going to develop from the discussions that surround the formulation of the flow-diagram.

		you as facilitator, are actually going to learn much about how t facilitate this kind of thing." "… so then you will be able to tell them, this thing that you are doing here just think about it this way. So your facilitation is also going to be responsive to what they come up with." "The facilitators in class will have to be very invested in this and you will have to train them." "Because once you get the first representations back you are going to start understanding how you students understand stuff. So that will tell you what they are doing right and what, in inverted commas, what they are dong wrong, in inverted commas."	The facilitator should be sensitive to this evolving understanding and make adjustments in response to this. Facilitators need to be responsive to the feedback obtained from students. The facilitator needs to adapt guidance in response to the feedback received from the student group. The unconventional or unfamiliar nature of facilitation in this type of learning environment requires a greater level of commitment from facilitators.

Focus group 7a

Category	Codes	Quote to support creation of category	Comment
Facilitating the development of the expert system Scaffold the class development of an expert system Converting the flow-diagram into a functional expert system	Class exercise Learn by doing	"Once we have got a flow-diagram representing their group's understanding of context, I want to do exactly what we did now. In other words, let's develop the expert system as a class and invite volunteers from the class to come and do it while the audience shouts instruction, support, guidance to those persons." "I found that when I was looking I kind of had an idea but as soon as you sit and do something yourself then you get the proper idea."	The previous class required the group to formulate questions in order to explore a particular communications concept or concepts imbedded within video clips. An algorithmic flow-diagram was then drafted, using the questions and answers prepared in the step above. This flow-diagram was then used as the basis for the development of a functioning expert system using CourseLab as an expert system shell. Students were first prompted to make a contribution to this development

Scaffolding the conversion of the flow-diagram into a functional expert system		"I think that it was necessary because we hadn't done it for a while and then we didn't really know what we were doing. So in today's groups it was necessary." "… it's going to refresh their memories pretty soon if they have forgotten some stuff. So I think if their prior knowledge is adequate then at this stage you won't have to work individually again like we did today."	through probing questions from the facilitator and then invited to sit at the workstation on which the development was taking place and, with guidance from the class, continue the development. The progression from formulating questions to drafting a flow-diagram to developing a flow-diagram was designed to articulate the link between a conceptual understanding and the development of a functioning expert system. Looking at the development taking place gives you an idea of what's going on but the real understanding or a confirmation of understanding only really takes place when you attempt it yourself. It may be advisable to work through the development as a class in order to refresh the students' understanding of how to use the expert system shell. This is particularly important for those who have not had much exposure to a similar development environment.
	Demonstration	"…facilitator can control the screen of the students. So you can physically take control of the screen and show them what you see on their screens." "… will the students also be able to see what you do on the computer on their own	A data projector was used for this demonstration / class development. Taking over or controlling what appears on the monitor at each student's workstation would allow students to see the development taking

		computers or will there be one overhead, cause that's not going to be practical, in those huge labs."	place clearly and would also allow them to try certain aspects of the development easily on their own. This would be particularly useful for larger groups where students are likely to disengage if they are not able to follow the development process easily.
	Means of assessing logic	"… the nice thing about building an expert system like that is that it is quite easy to assess, I don't know whether that is the right word, to assess whether their logic is valid. Because if you look at the screen when you do the screen preview kind of thing, they have got two conditions selected and they have got a display and if those things match up logically it means everything else must be in place." "It doesn't matter how they got to the answer; you just interested that they get to a valid answer. So what you can do is to go around and have a look at everybody's, you know, thingy, what they selected and what the display is and you know whether they have done it right or not." "A jig and you take something and you put it in a jig and if it fits then it works." "You don't necessarily know what the representation is but you know it's valid because it comes up with the "right answer."	The development of the expert system facilitates a close examination of the logic of the algorithmic flow-diagrams that were formulated during the design phase. It also allows for an examination of the validity of this logic.
	Group work	"… are they going work in pairs in small groups physically in the labs, that's something we should think about, cause it worked well now when we worked in a group together."	The first development exercise can be done as one large group (class) but it is advisable to follow this up with a similar exercise where the development takes place in

		"… the first one everybody does together with the lecturer so they see it on the screen like we did now, the second time you can make groups."	smaller groups where each individual student will have an opportunity to participate.
	Learn from one another	"… what I liked about this is the approach that we worked together as a group and that we kind of reminded each other and that we learnt from each other. So it was kind of a socio-constructivist approach here."	The class collaboration allows for a mutually constructed understanding and peer support. Individuals within the class have different levels of experience and understanding, collaborating allows for individuals to support one another.
	Feedback	"… remember when we learnt the software, if they had mastered it then, today might not have been that necessary and you will be able to pick this up when you start doing this and the students can immediately tell you what to do next then you will know that they are on the same page" "Unfortunately the only time that you are going to know whether they know enough is when you start doing this. Because if you start doing this and you don't get answers or you get the wrong kind of answers then you will know that they don't have the prior knowledge that you assume."	The response from the student group will give the facilitator insight into their level of understanding. The facilitator would need to be sensitive to this awareness and facilitate the development process accordingly. The facilitation needs to be appropriate to the needs of the students. The lecturer would need to be responsive to the feedback obtained from the student group and adjust the level of support appropriately.

Focus group 7 b

Category	Codes	Quote to support creation of category	Comment
Problem composition and formulation	Scenario	"How do we present the ill structured problem to the students? Gerhard: I think by giving them a scenario because that will be … the problem will be situated within a real-life scenario and it will	Problem must be situated within a realistic situation or set of circumstances.

		give the a little bit of information or structure." "So I think scenario, they must be presented with a scenario."	
	Composition of the scenario	"… you have to think about the communication in that scenario" "I think that when you describe your scenario you must have five components kind of covered in the scenario and the ill definedness of the scenario depends on how much information you give to them when you describe the scenario." "The problem is ill defined if they need more information they can go back to the video as many times as they want and get more information from that and then ultimately they can develop their expert system based on their understanding of what happened at that meeting. And I'm saying a meeting, you can use something else, it's just the first thing that came to mind." "The outcome should be implied in the ill structured problem? Gerrit: The information and stuff should be given in there, its just that you have got to make sure that they pick it up, they might not pick up that …"	The scenario in which the ill defined problem is embedded must be designed to allow for the learning outcomes to emerge. The open ended or ill defined nature of the scenario might allow for broad understanding of Communications concepts. The solution to the problem is not implicit in the scenario; so learning outcomes are not dictated or restricted.
	Ill-defined	"I think that when you describe your scenario you must have five components kind of covered in the scenario and the ill definedness of the scenario depends on how much information you give to them when you describe the scenario."	The solution to the problem (dilemma) must not be obvious or prescriptive. This may not elicit a representation of the students' understanding and will lead to duplication or regurgitation.

		"…you can describe that scenario in the greatest of detail and everybody will come up with the same kind of answer. But if you leave some information out … the more information you leave out the more ill defined your problem becomes." "The outcome should be implied in the ill structured problem? Gerri: The information and stuff should be given in there, its just that you have got to make sure that they pick it up, they might not pick up that …"	The ill defined problem must allow for the emergence of the desired communications concepts. Must accommodate the emergence of these concepts. 'Implied' within broad parameters. Without being prescriptive or overly directive the facilitator must ensure that the students detect the communications concepts embedded in the ill structured problem.
Providing support (scaffolding) for problem comprehension	Authentic evaluation	"My feeling about that is that it is just about as authentic as you can get it if you want to go the way of having an expert system developed to let somebody who doesn't know the expert system use the expert system because that's what expert systems are for, to get people who weren't involved in the development of the expert system." "…its more authentic then using you own expert system because you can read stuff into your own expert system but somebody else doesn't know the assumptions that you built into your expert system so that way round if they use the expert system and they use the display stuff to come up with the product."	Evaluating the expert system by asking other groups to use it to solve a communications problem. This would make the task more authentic and test the validity of the expert system logic effectively.
	Assessment	"I think that there needs to be a rubric that comes from the beginning through till the end certain sections, they are either competent or incompetent."	A rubric may be too prescriptive. Guidance needs to be given in terms of what an expert system is. The application developed must be an expert system that is comprised of the various components of an

		"I think it is important ahead of time to give them an assessment rubric, to tell them what it is that you are looking for and if you make the group self-assess or peer assess … as long as they assess in terms of you initial rubric." "…you get the group to critique the expert system and then they get the opportunity to go back and fix whatever didn't work well. But this takes time; that is my big concern with what we are doing here is that it all takes time."	expert system. All progress evaluation should be evaluated in terms of the students understanding of the expert system concept. Their applications must not be an aggregate of the various options selected but must rather be 'reasoned' response to a problem outlined by a novice user. Students must clearly understand what an expert system is and that effective progress in their development is dependent on this understanding.
	Facilitation	"I think that it should also be put in writing, the problem statement should be put in writing and as a support you show a video. Maybe … I think … it mustn't be taught or lectured, it must be in the background, and the lecturer must be in the background." "I think that's the right word is to scaffold the learning so if they ask you a question you ask them a question back, so you don't want to give them direct answers to questions kind of thing but you want to guide them in the right direction." "… you don't want to be directive but you want to elicit thought so if they ask you a question you don't tell go and do it like this, you tell them about different things that they should consider for themselves, so it's a provider of scaffolding not a …" "… he would be like a resource, so if they would get stuck they would ask him questions	The facilitator must perform a supporting role. The facilitator must provide the learners with guidance by questioning their thinking. Or posing questions that stimulate thinking and provide guidance. Must not provide the students with direct answers to questions but must provide guidance concerning along which lines they should be thinking. The facilitator must not be too meddling and intrusive; he must respond to the students' enquiries rather than impose his advice on them. The facilitator must ensure that the design and development explore appropriate communications concepts. The facilitator must carry out sufficient monitoring to ensure

		but he doesn't hover around them and check that they are doing it correctly; so they go to him if there is something that they are not quite sure about, kind of supporting them if they need him." "…when you facilitate you have to make sure that they have got something in their model that says *context*, they can use another word for it, that's fine but they must have something that says *context* and they must have something that says *product* and they must have something that says *audience* or what ever the case may be" "…if don't make sure that that happens, they can come up with a model that is kind of an incomplete model and in our environment we have a responsibility to actually convey, umm, a proper model." "… they get all the information from the ill structured problem that they need to get from it, so you need to guide them in that direction." "… if you see there are some shortcoming you do your, *what about this what about this* question; move them in the right direction."	that the students are exploring and representing appropriate communications concepts. The facilitator must ensure that the students grasp the rationale behind the ill structured problem.
Group collaboration / interaction	Compare and contrast understanding	"… we used to do home groups and specialised groups, so you get … you get two sets of groups. So for every specialist group you give one component to go and explore and then you reconstitute. So they work in different groups on the components and then they come into the home groups and they share their understanding and in that way you do have that where …"	Allowing different groups to work separately on the same task and then at the end of each development or planning session the various groups would get together to discuss their individual development. This would facilitate the comparison and contrasting of ideas and understanding. Take the

		"What if after a period of development I combine groups and they take the best of each and they come up with one? What do you all think of that concept?" "… like at conferences and work sessions when you do like breakaway groups and people come back and they do report backs." "… if you have your different groups go and construct models, come back and report back to the bigger group, but then importantly they have to go back to their groups and redefine their understanding." "… perhaps an easier way of doing it rather than a home group specialist group thing because the numbers in the class will affect how the groups work."	best of all the development activities to reinforce conceptual understanding. Facilitate the exchange of ideas.
	Home group	"… we used to do home groups and specialised groups, so you get … you get two sets of groups. So for every specialist group you give one component to go and explore and then you reconstitute. So they work in different groups on the components and then they come into the home groups and they share their understanding and in that way you do have that where…" "… perhaps and easier way of doing it rather than a home group specialist group thing because the numbers in the class will effect how the groups work."	Formulation of the idea of various groups getting together to compare and contrast design and development ideas.
	Interaction	"I think that more leaning takes place when interactivity takes place and discussion takes place."	Socio-constructed understanding, etc.

Focus group 8

Category	Codes	Quote to support creation of category	Comment
Construction / composition of the problem statement	A brief	"… a brief is much more, umm, open in terms of not limiting the students to a specific scenario and its much less prescriptive and the fact that it is on paper so that you can go back to and refer to it again."	Instead of describing a particular situation, give the students a brief that outlines a concept. The problem is not situated within an artificial scenario but rather in the form of a conceptual brief that could be applicable to a variety of situations.
	Contains background information	"…"its long, but I think that it has all the background and the information and it's not obvious what they should do. They will have to think and that's why Eunice and I sat for a while and decided what it is that we will have to do."	The brief provides background information to the concept that needs to be explored. It sets the scene without hinting at an obvious solution.
	Not straight forward	"… it is not straightforward. Your have to go through that and decide … you have to in the group decide what the actual problem here is. You have to see what the problem is before you can carry on and develop this."	The problem statement was in the form of a brief that outlined a concept. It was not in the form of a clear-cut scenario where a solution is implied by the situation itself. It was open-ended and could accommodate a variety of approaches. An obvious problem is not imbedded in the problem statement. The problem statement presents the students with a broad outline of a situation that is reasonably intangible. The problems are more of a conceptual nature and are not rooted in the particulars of a situation.
Engaging with the problem statement	Constructivist	"… if handout the homework assignment ahead of class that means you are directing what happens during class because they know	If the facilitator hands out or makes the students become aware of the problem statement too soon; this

		that they will have to find answers to these questions. What will happen then is that they will use the interactions to answer those questions which is not the constructivist way. If you handout the instructions at the end of the class, they don't have the resource of group discussion ahead of them to get the answers, so what they will have to do, they will have to consult their mental model of what occurred during the course of the event to answer the question so probably that is the more constructivist way of doing it." "… the open problem that you gave them fits nicely into your constructivist approach. Because it's open-ended and it's ill defined so I think it's a very well constructed open-ended problem that fits nicely into your premise of constructivism."	will influence how they construct an understanding through class discussions and interaction. If the problem statement is handed out after the students have constructed some conceptual understanding of the Communications concepts: they will be encouraged to reference their own mental models of this understanding when designing a solution to the ill structured problem. The open-ended nature of the problem statement allows or accommodates a variety of solutions. There is not obvious answer.
Providing support / scaffolding when engaging with problem	Facilitator's role	"I think the fact that the facilitators should be available to provide scaffolding is extremely important. The students shouldn't, they shouldn't start working and then be left floundering." "… the fact that you were on hand; we could ask you something, it didn't slow down the whole process, we could ask you a quick question; we moved on. It's not something we have got to ponder and sit and try and work out."	It is advisable for the facilitator to be available to guide the students. The open-ended nature of the problem statement may disorientate students. These students may require guidance from the facilitator to avoid becoming disillusioned. It is advisable that the facilitator provides timely guidance.
	Flow-diagram	"Sandra and I enjoyed working on a flowchart. Just sorting out the questions first and then just get a mental picture on paper and with all the layers what that mean. The flowchart proved to us that if we express it this way that that would be a logical next step. It actually led	Cognitive load?

		us in the direction of getting to something that would be able to answer different questions regarding different things.”	
	Free to ask questions	“… you need to establish that the students must ask questions when they want to ask questions. Because what the question does, is it gives you an indication of their understanding, and you cant really scaffold appropriate unless you know what they know, and the way in which you know what they know is they ask a question and as soon as they ask you a question you know what they are thinking and then you can scaffold appropriately. So that is very important that they will have the freedom to get up in class and ask you the question.”	Even though the students are required to design and develop and expert system on their own with reference to an ill structured problem statement, they should be encouraged to pose questions and request guidance from the facilitator. This will give the facilitator an indication of what sort of scaffolding the students require. This will place the facilitator in a better position to asses the students’ cognitive understanding.
	Just in time	“What happened was that that was just in time, it was just at the right moment that you did that. The learning was easy then because you weren't trying to learn software using some abstract scenario to build something. You were learning functionally, you know that this is what you need to do and you going to use software and now we are using the software to try and achieve something specifically.”	The problem statement was presented to the students after they had been given an opportunity to work through a worked example. This placed them in a better position to formulate / undertake / develop a solution to the problem. This provided them with insight into how to approach the ill defined problem.
	paper-based	“… the fact that it is on paper so that you can go back to and refer to it again. Because as we went along we wanted to go back and consult it again because you build on your own understanding, it’s levels.”	The problem statement provided a reasonably detailed amount of information that students could refer back to when exploring their own understanding when exploring possible solutions to the problem.
	Scaffolding	“I think we probably moving in the right direction by having a very broad, almost undefined introduction. And then scaffolding your way toward a more defined problem	Providing background, conceptual information to allow the students to gain a greater insight into the problem. Progress toward a more

		setting, more defined definition of what the outcome is. I think that's a good way of doing it.” “So it makes the learning easier because you have got in mind what you want to get out of the system and now you are learning how to do that quickly, it was just the right moment. That made today's exercise much easier because now I could actually sit down and use your software to do my mental representation.” “I think the fact that the facilitators should be available to provide scaffolding is extremely important. The students shouldn't, they shouldn't start working and then be left floundering.” “… you need to establish that the students must ask questions when they want to ask questions. Because what the question does, it gives you an indication of their understanding, and you cant really scaffold appropriately unless you know what they know, and the way in which you know what they know is they ask a question and as soon as they ask you a question you know what they are thinking and then you can scaffold appropriately. So that is very important that they will have the freedom to get up in class and ask you the question.” easily	focused problem once background to the problem has been provided. Working through the examples provides the students with insight into various ways to address the problem without providing them with definitive solutions. The progression from working together with the facilitator to develop a simple example to working in small groups to design a solution to an ill-defined problem. Facilitator on hand to provide timely support. Facilitator can gage the level of scaffolding required by the students through the questions that they ask. The leaning environment must encourage the students to ask for assistance when they need it. Even though they are required to design a solution on their own, they must be given the freedom to ask questions when they require assistance.

Focus group 9

Category	Codes	Quote to support creation of category	Comment
Engaging with the expert system	Code statements	“I struggled with the fact that we did the coding …y our taught us the coding that we will have	A lack of exposure to a programming environment leads to

shell		to use about two or three weeks prior to today and suddenly I had to make that shift again and it was there vaguely but I struggled just to get that in place and that took time, to understand how to do the coding again using the program." "I made notes the last time that you showed us to do the IF and the THEN and the questions etc, and now my notes two weeks along the line does not always make sense to me as it did at that stage. So I agree with Eunice; if following period if I had used that and done that then I would have remembered and also if I do it myself then I would have seen ok this is how it works or this is a problem, call you; you showed me." "My problem just now is that I don't know where to put in the IF statement I understand that I have to do that and then it's going to show there. And another thing, if it doesn't work I don't know where to go back and look for the problem to correct the problem. If you talk about it making sense and on paper … .But then I don't know where to find that. I can't remember." "I have to do it myself; I saw what Eunice did but for me because I'm not used to this and I'm right brained totally. For me what would help is if we did it immediately afterwards and I hade notes and the facilitator on hand and I could do it, try it myself, and if I make a mistake I ask you and then rectify." "And then during the next period I will have to	confusion. Too much time lapsed between the demonstration of inserting code statements in the expert system and when the group needed to develop their own expert system. Even notes did not make sense to some learners. The facilitator needs to be on hand to provide assistance when the students begin to interact with the expert system shell. One must not assume that the students will fully remember how to insert coding statements and how to structure coding statements. The facilitator must be aware that students may not be familiar with coding conventions or concepts and must be on hand to assist.

		do it again otherwise if time lapses, gone out of my head.”	
	Hands on	“I have to do it myself, I saw what Eunice did but for me because I'm not used to this and I'm right brained totally, for me what would help is if we did it immediately afterwards and I hade notes and facilitator on hand and I could do it, try it myself, and if I make a mistake I ask you and then rectify.” “…doing it for yourself is the best way because if you make mistakes you learn from your mistakes because you have to do it over and over because you have to get it right.” “I would also recommend to the students that there is not only one person doing the typing because when I was following what Gerhard was doing sometimes you lose his line of thought but as soon as I started doing the second one on my on then it really settled in my mind.”	The practical development of the expert system is important for the understanding of expert system logic. The concepts are not fully grasped when members of the group are simply observing the development process taking place. Learning is enhanced when students are encouraged to be directly involved in the development process. Students may not full understand the concepts being explored unless they are directly involved in the development process. Mistakes force the learners to revisit, not only the coding syndic, but also the logic of their expert systems. Students learn from these mistakes and revise thinking.
Representing understanding using an Expert System	Aggregate of options	“Remember last week I made the comment, I was kind of unclear about this expert system thing until I started seeing that if I select this and I select that and I select that what the response is at the bottom and then what I got here… remember what we did was to say, the setting is informal and the subordinate and then our display was that the setting was formal and the subordinate, which is not and expert system its just an aggregation of what your selections were at the top so we then understood that the question needs to be different and that the program needs to have	It is important that the students understand what an expert system is. It is not a summary of various options selected but involves inferences made as a result of options selected. The display line or output of the expert system will indicate whether the students have understood the logic of an expert system. It seems to be common for the developer to presume that the advice offered by the expert system involves an aggregate of

		some kind of intelligence that interprets your response and gives you an expert answer.”	the options selected by the user. The concept of an inference engine needs to be carefully explained.
	Faulty logic	“… that we did today I found very useful because the previous times Sandra and I did a flowchart and the actual, I don't know what to call it, the coding, it showed us the faulty logic in certain instances.” “…because we made a mistake with our coding and we also had to re-visit our logic but not only the logic of the programming language but also the logic of our CMAPP structure. Does our opinion make sense?” “What I noticed where I saw that higher-order thinking was definitely taking place was that this particular group realized that that the one question was not applicable if the other option was selected and that to me is a huge understanding of what we are doing and then they came to me and asked how do we get this to happen it won’t make sense if that question is there, and that is directly related to the domain that we are exploring.” “…because we made a mistake with our coding and we also had to re-visit our logic but not only the logic of the programming language but also the logic of our CMAPP structure. Whether our option do make sense.”	The development of the expert system using CourseLab as an expert system shell demonstrated faulty logic. The development process encouraged the students to examine the logic of their expert system design more closely. The faulty logic is revealed during the development process. The development of the expert system revealed errors in thinking and often extended the thinking process. Because the students have to apply the design, often faulty, incomplete or deficient logic is exposed. Even mistakes made during the coding process encourage students to re-explore the logic of the domain. The learner (developer) would need to examine both the code and the flow of logic applicable to the domain in order to discover the reason for a particular output (result, consequence).
	Flow-diagram	“It helped us to develop in the IF THEN of an expert system: so we had to go back to the underlying rules and make sure that those were in place.”	The flow-diagram lays the foundation for the development.

	Higher order thinking	"I think it's absolutely higher order thinking because if you are solving problems the whole time, regarding your logic in the programming side but also the logic in the CMAPP, the communication theory side." "… everybody is talking about the software; nobody is talking about a conceptual understanding of the model. So that is not happening at this stage, higher-order thinking about what the model looks like is not happening." "At that stage when you are working on the display line and you start reflecting about what an intelligent system is and how you have got to ask the question to get to the response … to get the appropriate feedback kind of thing. I think at that stage your higher-order thinking is going to be quite a lot at this stage, I'm not to sure." "The reason why I made the comment that higher-order thinking about the model is not taking place here is because nobody mentioned it; I actually listened for that. Everybody is talking about the program issues here so maybe higher-order thinking about the program but not about the model." "I think once you get to the display side of this exercise and you start really seeing what your choices above do to your feedback at the bottom that's when you really start getting the interrelationships between the questions that you are asking and the final influence it has on your message."	Constant problem solving encourages higher order thinking. Revisiting programming code to discover faults or to determine why the program is not working as it should requires constant problem solving. Becoming familiar with the development environment detracts from the conceptual exploration of the domain. (does it? Does revisiting the programming logic, etc. not force a close examination of the domain?). Working on the inferences that need to be drawn by examining the choice combinations is where the bulk of the higher order thinking takes place.

Focus group 10

Category	Codes	Quote to support creation of category	Comment
The expert system shell functioning as a cognitive tool.	Broad understanding	"… how has that modified your understanding of a formal context? Eunice: It has, because I would say formal is, formal is if the people wear suits in an office that would be the off the tip of your tongue's answer that you would give. But formal can take different shapes and a student could … or someone approaching the expert system could come with a specific idea what they have seen, so will the expert system be able to give advice based on that because there are so many variables and factors that come into that." "I think at this level when you start coding that kind of stuff, that's perhaps the learning that's going to take place. It's about what things to look for if you look at formal and informal, what kind of things in real life, if you are in a setting what kind of things are you looking for to decide whether that's informal or formal. Because that influences the question that you are going to ask."	The complexity of the domain becomes apparent through the process of developing an expert system that is designed to mimic the expertise of a human expert. This design and development facilitates a deeper exploration of the domain. In order to formulate appropriate questions, the developer needs to have a certain level of insight into the subject domain. The developer needs to explore the subject domain in order to formulate appropriate questions. This insight is further explored and enhanced when the developer is required to infer advice from combinations of answers.
	Cognitive tool	"So the reason why I think that people need an expert system is to tell them be very basic, if you do this then go on to this or this means … if you choose a suit then it is formal. So obviously people will learn something else not just the programming of that."	A tool that facilitates the learning of a subject domain.
	Faulty logic	"… we worked on the flowchart beforehand because that made sense to us. But when we started working on the programming we saw that there were some flaws in the flowchart	Developing the expert system using the expert system shell facilitates a deeper exploration of the subject domain. This

		that we did in the beginning." "For me still this works better to initially just pinpoint the questions for myself and then what I think should work and then when we do it and see that it doesn't work then we can go back and say ok why didn't that work was there something wrong with our questions here or the IF THEN statements." "… what was missing in the flowchart? Sandra: Maybe it was the questions, there wasn't a specific IF THEN statement to get to an event in the end, and I think that was maybe the problem." "What I found was that I got stuck at a certain question and then I realised that I am actually almost giving them multiple choice. Choose one and then the next but real life does not work like that."	development facilitates a closer examination of the logic expressed in the initial design. Deficiencies in the logic of the flow-diagram are revealed when they undertake the development of a functional expert system. Need to realise that the expert system must not just give you an aggregation of the options chosen but need to make an inference the way a human expert would.
	Higher-order thinking Reflect on learning	"… what's brilliant about the expert system is that students have to reflect on their learning, so its not just … yes they create a database of information but if they get this right they will turn this information into knowledge that they can apply. So I think that this makes this like constructivism, higher-order learning. Its not just learning a collection of information they have to infer knowledge to arrive at a decision."	The development of an expert system that facilitates a process of reflection. Students have to explore their understanding of a subject domain. They apply their understanding to the development of a functional expert system. Construct a representation of their understanding. This encourages them to reflect on the subject domain.
	Logical thinking	"… how is this influencing the depth of understanding that you are achieving? Sandra: Umm, it did because I'm not a logical	Forces you or encourages you to think logically about a particular subject or concept. The development of the expert system

		person but if you struggle a little bit then you understand if you do this then this will happen if it doesn't happen then it means something is wrong; then you have to go back and find out why and think but why didn't it work. What went wrong, so I think that there is learning in that." "You have got to go back to the real-life situation and think, what would they see there and you would have to make provision for that. And also if I worked through the whole thing it would be IF THEN IF THEN but I could only work on the one leg of formal and that would disregard any other choice that the students would have made and we would have had to do a whole different level which I'm not sure we would have approached that." "Gerrit told us that Gerhard and they worked basically; you put in your IF THEN statements from the bottom so that you don't have a choice. So the logic developed and my ideas of the concepts developed also. And I also got and aha moment about OK this is what an inference engine should be doing." "… what happened to me in terms of learning about the model itself and the components of the model once we had the aha moment of what an inference engine really is then it forces you to start looking back at what it is that you are looking for to decide, for example, that the tone is formal or the tone is informal. Umm, and once … what happens then it forces you to pay attention to what the fuzzy indicators of formal or informal."	highlights faulty or illogical thinking. Explore the gaps in you logical understanding of a concept. Encourages the developer to visualise or explore a real-life or authentic situation. The logic that an authentic situation would demand or impose on an individual's understanding. A certain amount of logical thinking would be necessary if an individual engaged with an authentic situation (Function successfully within an authentic situation). Expand thinking to include the logic that a real-life would demand of an individual. Exploring the logic necessary to develop the expert system encourages you to explore your conceptual understanding of the domain. New way of looking at or thinking about a subject allows the developer to make unexpected discoveries. The understanding or realisation of what an expert system is allows or encourages the student to consider the subject domain with greater insight. Encourages a deeper more inclusive or comprehensive insight into the subject domain. Consider the subject domain from different

		"I think that at this level of coding that's where the learning is going to take place. I predict that the interdependencies between the different components in getting to your final product, I think that is going to become apparent right at the end when you start working on your display line."	angles. Formulating the content of the display line is where the real deep learning is going to take place.

Addendum B

Research participant information sheet-Students

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Office of the Dean

Research participant information sheet

INFORMATION COMMUNICATION TECHNOLOGY AS A COGNITIVE TOOL TO FACILITATE HIGHER ORDER THINKING

My name is G W Collins and I am currently conducting a research project, the purpose of which is to reflect on the design process followed when developing a learning intervention that uses an expert system shell to model understanding in order to develop higher order thinking skills. Before you agree to participate in the project you should fully understand what it is all about. If you have any questions, which are not fully explained in this document, do not hesitate to ask me or contact me, my supervisor or the Chair of TUT's ethics committee at the following numbers:

- **Gary Collins** : Tel. 082 518 6600; collinsgw@tut.ac.za
- **Dr WA Hoffman** (Chair, TUT's Ethics): Tel. 012 382 6246; hoffmannwa@tut.ac.za
- **Prof J Knoetze** (Supervisor): Tel. 012 420 2886; jknoetze@mweb.co.za

WHAT IS THIS PROJECT ALL ABOUT?

This project is about reflecting on the process involved in the design and development of a learning intervention that uses technology as a cognitive tool in order to facilitate the development of higher order thinking skills in foundation English Communication Skills students at TUT. The reflection will be concerned with the process followed by an instructional designer when designing this learning environment. This reflection will lead to the formulation of design principles. These design principles will include the essential characteristics of the intervention as well as a description of the process that might be followed in order to design and develop a similar intervention.

WHAT WILL YOU HAVE TO DO IF YOU ARE PART OF THE PROJECT?

You will be asked to participate in a learning program that requires you to use technology as a cognitive tool in the form of an expert system shell. You will then be asked to fill out a questionnaire, after which a group discussion will be held to obtain your impressions of the computer assisted learning experience.

WHAT BENEFITS WILL THE PROJECT HAVE FOR YOU AND OTHERS?

The design principles that will be formulated will serve as guidance for instructional designers and lecturers who wish to design and develop a learning environment under similar circumstances. A copy of the final thesis will be provided to the TUT Dean: Humanities and the TUT Director: Teaching and Learning with Technology for notification and implementation of the research findings.

THE RESEARCHER'S ASSURANCES AND COMMITMENTS

Participation in this project is voluntary. You are free to withdraw your consent to participate at any time without having to provide any reason for your decision. Withdrawing your consent will be accepted without any penalty or future disadvantage.

All the information that you provide during the project will be handled and stored confidentially. This means that access to your data will be limited strictly to the researcher. All personal identifying data will be removed/masked on transcriptions and all project documents. Your identity will not be revealed during or after completion of the project, even when the results are published or used in any format.

If you so wish, I shall be glad to give you feedback regarding the analysis of your data and the overall analysis of the project.

Non participation in this project will not have any detrimental influence on your academic assessment in any course.

All parts of the study will be conducted according to the internationally accepted ethical principles of qualitative research.

A LAST REQUEST

The researcher would like to request your permission to do the following during and/or after the study, namely to:

- audio-record our interview/s for data analysis; and
- use direct quotations from our interview/s in the final project report, journal articles and/or other formal presentations of research results.

If you are still willing to participate I shall be glad to make specific arrangements for the research interview. I will then require from you to sign an informed consent document as a formal acceptance of the information contained in this information document.

Building and office no: T09
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Addendum C

Research participant information sheet-Design Team

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education
Office of the Dean

Research participant information sheet

INFORMATION COMMUNICATION TECHNOLOGY AS A COGNITIVE TOOL TO FACILITATE HIGHER ORDER THINKING

My name is G W Collins and I am currently conducting a research project, the purpose of which is to reflect on the design process followed when developing a learning intervention that uses an expert system shell to model understanding in order to develop higher order thinking skills. Before you agree to participate in the project you should fully understand what it is all about. If you have any questions, which are not fully explained in this document, do not hesitate to ask me or contact me my supervisor or the Chair of TUT's ethics committee at the following numbers:

- **Gary Collins** : Tel. 082 518 6600; collinsgw@tut.ac.za
- **Dr WA Hoffman** (Chair, TUT's Ethics): Tel. 012 382 6246; hoffmannwa@tut.ac.za
- **Prof J Knoetze** (Supervisor): Tel. 012 420 2886; jknoetze@mweb.co.za

WHAT IS THIS PROJECT ALL ABOUT?

This project is about reflecting on the process involved in the design and development of a learning intervention that uses technology as a cognitive tool in order to facilitate the development of higher order thinking skills in foundation English Communication Skills students at TUT. The reflection will be concerned with the process followed by an instructional designer when designing this learning environment. This reflection will lead to the formulation of design principles. These design principles will include the essential characteristics of the intervention as well as a description of the process that might be followed in order to design and develop a similar intervention.

WHAT WILL YOU HAVE TO DO IF YOU ARE PART OF THE PROJECT?

You will be asked to work through a tentative design of a learning event that uses computer technology as a cognitive tool in the form of an expert system shell. You will then be asked to participate in the pilot design of a questionnaire that will be presented to the student sample, after which a group discussion will be held to obtain your impressions of the computer assisted learning experience.

WHAT BENEFITS WILL THE PROJECT HAVE FOR YOU AND OTHERS?

The design principles that will be formulated will serve as guidance for instructional designers and lecturers who wish to design and develop a learning environment under similar circumstances. A copy of the final thesis will be provided to the TUT Dean: Humanities and the TUT Director: Teaching and Learning with Technology for notification and implementation of the research findings.

THE RESEARCHER'S ASSURANCES AND COMMITMENTS

Participation in this project is voluntary. You are free to withdraw your consent to participate at any time without having to provide any reason for your decision. Withdrawing your consent will be accepted without any penalty or future disadvantage.

All the information that you provide during the project will be handled and stored confidentially.

This means that access to your data will be limited strictly to the researcher. All personal identifying data will be removed/masked on transcriptions and all project documents. Your identity will not be revealed during or after completion of the project, even when the results are published or used in any format.

If you so wish, I shall be glad to give you feedback regarding the analysis of your data and the overall analysis of the project.

Data collected will not in any way be used or released for promotion and/or performance evaluation purposes.

All parts of the study will be conducted according to the internationally accepted ethical principles of qualitative research.

A LAST REQUEST

The researcher would like to request your permission to do the following during and/or after the study, namely to:

- audio-record our interview/s for data analysis; and
- use direct quotations from our interview/s in the final project report, journal articles and/or other formal presentations of research results.

If you are still willing to participate I shall be glad to make specific arrangements for the research interview. I will then require from you to sign an informed consent document as a formal acceptance of the information contained in this information document.

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Addendum D

Informed Consent Form

INFORMED CONSENT

INFORMATION COMMUNICATION TECHNOLOGY AS A COGNITIVE TOOL TO FACILITATE HIGHER ORDER THINKING

Researcher: Mr G W Collins, Department of Applied Languages, Faculty of Humanities, Tshwane University of Technology

*Instructions: Complete all the questions in this document by marking (**X**) the relevant block in each question. Then sign your initials at the bottom of page 1 and provide your full signature in the relevant place on the second page.*

1. Have you read the Research Participant Information Sheet?

YES	NO

2. Have you had an opportunity to ask questions and discuss any unclear project issue with the researcher?

YES	NO

3. Do you understand that participation in this project is completely voluntary?

YES	NO

4. Do you understand that you are free to withdraw from the project and/or interview/s at any time, without having to give a reason for withdrawing, and without any penalty or future disadvantage?

YES	NO

5. Do you understand that all the information you provide during the project will be confidentially handled and stored?

YES	NO

6. Do you understand that you will not receive any monetary or other form of reward for participating in the project?

YES	NO

7. Do you agree to take part in this project?

YES	NO

______________________________ ______________

Research participant's signature Date

______________________________ ______________

Researcher's signature Date

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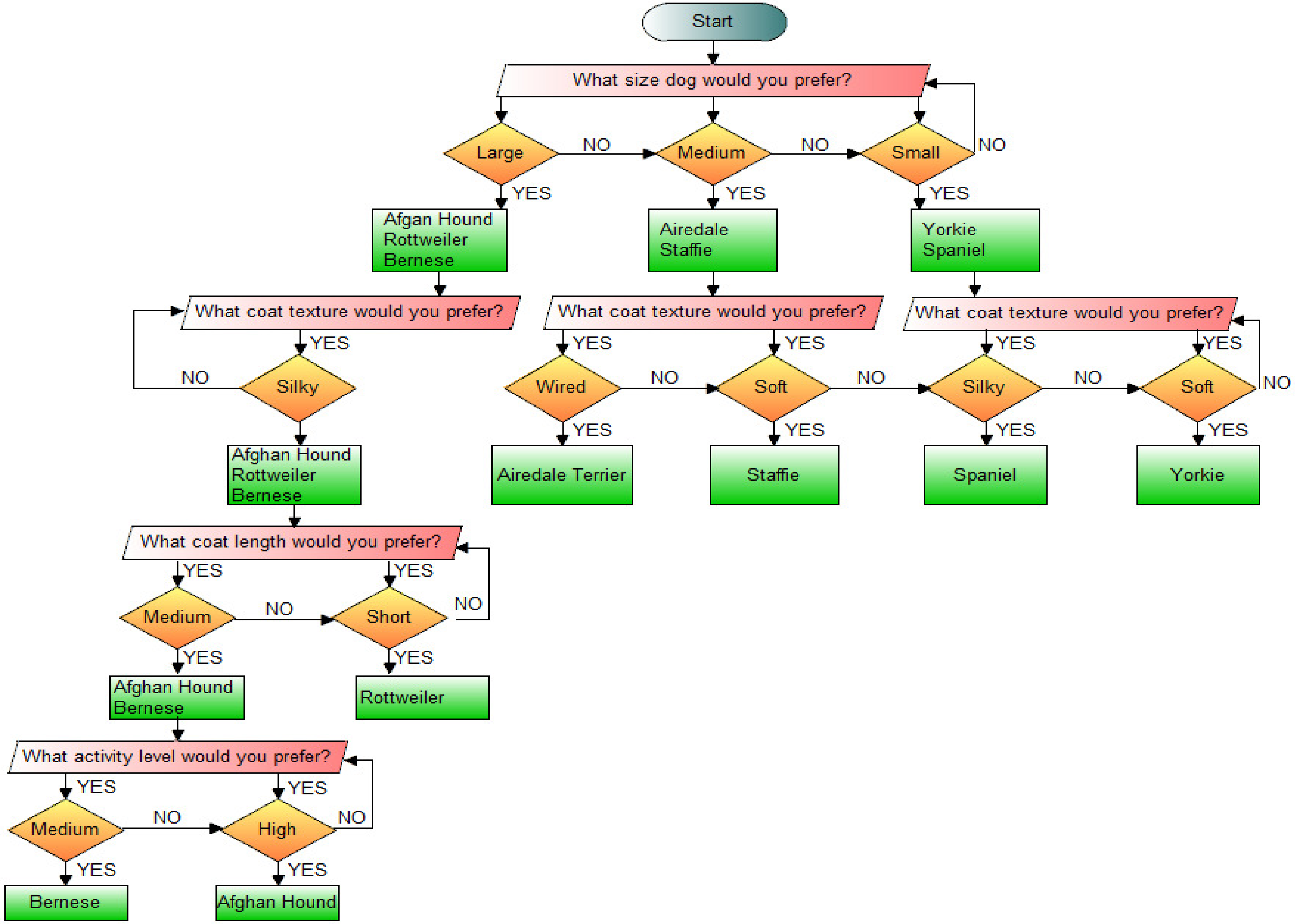
Addendum E


Start
What size dog would you prefer?
Large
NO
Medium
NO
Small
NO
YES
YES
YES
Afgan Hound
Rottweiler
Bernese
Airedale
Staffie
Yorkie
Spaniel
What coat texture would you prefer?
What coat texture would you prefer?
What coat texture would you prefer?
YES
NO
Silky
Afghan Hound
Rottweiler
Bernese
Wired
NO
Soft
NO
Silky
NO
Soft
NO
YES
Airedale Terrier
Staffie
Spaniel
Yorkie
What coat length would you prefer?
YES
YES
Medium
NO
Short
NO
YES
YES
Afghan Hound
Bernese
Rottweiler
What activity level would you prefer?
YES
YES
Medium
NO
High
NO
YES
YES
Bernese
Afghan Hound

Addendum F

Transcripts of the focus group interviews held with the design team

(No editing of responses)

Transcript of focus group interview held on 20 January 2011

I: Ladies and gentlemen, initial impressions of what we've just seen; who would like to begin?

R2: Well, I must tell you that this is quite an interesting topic and I think that it is quite a challenge for you and whoever is going to work with you. I think that your problem that you want to solve, the problem that we are encountering here at TUT, is relevant and the idea that you have is very interesting, something new and it's a challenge as I've just said. For me to be more practical, I think I understand your thinking pattern, I understand where you come from. The only thing is that I would have liked to see how the expert system functions, but we'll do that next time that we meet. Those are my initial impressions.

I: OK, what possible challenges do you see?

R2: To me it is still a little unclear, 'cause I see that it is still a little unclear for you as well, how you will actually implement this with a group of students, so for me to make definite … . So the pitfall for me at this stage is that it is not quite clear for me. But I mean it's part of this process.

I: It's not clear for you regarding how it is going to be implemented?

R2: Yes.

I: Thanks R2. Who else?

R3: So you're speaking about pitfalls, so you will probably see it when we are going to implement it for you, so maybe you will see with us that we can't do it so I don't know how the students are going to do that. No. I just want to know about the material that you are going to use and that what you are using… What I'm trying to understand here is that you are going to give them information, not information that they already know about but something that they should know something about but then develop as they go on to … in order to get them to a higher level of thinking. The material that they are working with, they must understand at least a bit about what is going on, otherwise I think they will not be able to … you know, ask the right questions because I see that your expert system, you have to ask the right question, you have to think about the right questions as well and if they don't really understand, I think maybe … although on the other hand if they don't understand they might ask relevant questions and get to the answer that you need.

I: And your initial impressions?

R3: No, I think that it is a very interesting concept, I'm totally technology challenged so if I can go through this I'm sure that your students will be able to do that as well. No, but I think that it is a very good concept, I think that you have a very good thing here, something that when you are done, sell it to other universities or something but I think that it is something that can be used. The problem maybe is now for your class, that the thing with technology is, the problem the way I see it is that not everybody has access to technology, so now the students are going to be in class; so now if you are going to use this probably it is going to be in the university where there are facilities etc. available.

R4: I think that it is a very exiting research that you are doing because if you take a look at the context we are in at TUT and the challenges that we are faced with and the students who we teach I think that we are currently stuck in using technology in a way that will just perpetuate the problem, the behaviouristically based software and not replace what they are doing. So I think that it will be very exciting, I think that the most exciting but for me will be to see how the students respond to it and if there is resistance and if once they realise that if they are going to work on this and build this, how they will respond to that. Although I think that once they pass the first obstacle, I do expect to see that they are going to enjoy it. And it is maybe going to change their perception of their own abilities and I think that is important because I think their awareness of what they are able of will be challenged so some boundaries will be shifted there.

R5: I think that the biggest challenge would be the implementation in terms of contact time, as R4 said they will only have access to computers and hour and a half a week and that's it. Most of the Soshanguve students don't have computers at home. So that's going to be the biggest challenge I would say. And what I remember last year we worked for about two weeks with the expert systems and the response from the students was amasing at that time, I think that it is exciting and the students are going to enjoy it that's for sure. And the last thing I think that it is crucial at the university level to implement it, I think that it is great because I think that it is something that is always a problem… I think that it is the purpose of a university is to get them to start thinking, it's actually too late but at least we can try.

R6: I'm also very excited about Jonassen's mind tools and the expert system is one of the mindtools that he encourages lecturers and teachers to use. And I was introduced to the mindtool concept a few years ago, we worked on creating an expert system to identify birds and that really helped; I mean the birds that we had to identify, their characteristics still stick in my mind so I think that it is an excellent way of learning because creating an expert system goes hand in hand with doing research and discovering information itself. So I'm also very excited about this it's just to create the shell now of how to implement this in class, how are we going to go about doing that, but like R5 said we did two years ago as a short trial run and there are definitely possibilities.

I: What are the main challenges?

R6: I think the main challenges are the time and access to computers, as R5 said, and creating the shell and also having enough time for the students to be able to create the expert system in class, but I think that that can be done.

I: Thank you all very much.

Transcript of focus group interview held on 2 February 2011

I: Just general impressions of what we've done today.

R3: Okay, I think that the students would find it very interesting. It is a new way of learning to them. It's not something they're used to. I also think that they will enjoy developing something for themselves, instead of being given something as per usual in the classroom.

R6: I think if you are going to use IT students, that's probably going to be a good selection, given that they need to work with a little bit of programming logic, because they might be a little bit more familiar with the programming logic than the kind of general student. I know with us we kind of have a basic idea of what programming logic is, but not really enough to do something constructive with that, but if they are IT students, they might have already encountered stuff and they might have learnt how to write that into a program so they might be a little bit more aware of syntax per se of the programming logic whereas we are just familiar with the concept of programming logic. So I think your selection is a good one.

I: But if the selection was different?

R6: I think you will battle if you work with logistics students, for example.

I: We need to find a way of overcoming that obstacle.

R6: Yes

R3: Just a concern of mine, is time. Time. Because one always under-estimates how long this would take and I think even to the students … even if they are IT students it might be a totally new concept. So time … you'll have to consider that very carefully.

R6: I think you should also consider having it facilitated face to face. Rather than working off a printed sheet. Because what happens then, is if you do step-by-step and they have to follow you step-by-step as soon as there's an issue they you can actually go and address a specific question that they've got. And I think the variety of problems that you will encounter will be quite vast, so to trying to cater for everything on a handout is kind of difficult. You might give this to them as a reference for later on. But the first time they encounter that you actually facilitate a simple example but on a face-to-face basis. And as we spoke earlier perhaps on that campus if you use "Netop" might be a good way to do that.

R4: Some students might run ahead of the others as well in their own time.

R5: I think also many of the IT students who are doing communication now, some are 3rd year. 2nd / 3rd year generally, by that time they already know programming logic. So I think they will … that they will not struggle that much. But let's say a group of logistics students might struggle to grasp the concept of programming logic, but I think just to support them, give a hand out but also maybe go through it step by step in class as well; to pre-empt any problems that they might have.

R6: That's just a further comment about a handout, is given that group of students, for example, if you test their language proficiency it's not really that good. And then to give them a handout with proper English written on it might not be that useful to them.

R3: Yes, and I also think there's the terminology used in the handout, might be an obstacle. You'd need to explain that sometime.

R5: Maybe more graphics and fewer words maybe. Yes, I haven't thought about it, but it might be a problem.

R6: And really simple language and you're going to have to predefine terms all the way. So if you want to use variable, you will have to tell them in simple English what a variable is. With an example. That's why I'm saying if you are going to use paper, you will end up with quite a hefty manual if you have to predefine everything and give the examples. Even if you explain to them what a variable is, it's still not going make sense until they see an example. Not the IT students as much, but the broader population is going to have difficulty with that.

R5: Generally the handout is a good idea, I think. Step by step guide to take them through this, because I'm also not that clued-up. Definitely not on programming and this is really … it does help. And I did this two yrs ago and I've forgotten a lot and this really helped me to remember what I did 2 yrs ago. So it's a good idea.

R3: And especially if you regard that this will be the tool to design the expert system in the end. It shouldn't be an obstacle. They should have a handout for reference later on. You explain and then in their own time they can come back and look it up again.

R4: I think, also, something we should consider as we go through this process. In what way are we using higher order thinking? Because that's what it's all about in the end. So maybe that's just something to consider when we go through this process.

I: So besides the handout and R6's suggestion of a face-to-face demonstration, what other tools can I or we use to overcome the obstacle of getting to know the expert system shell?

R6: Remember that we get the Camtasia recording, so screen capture because maybe if we do the screen capture and we can split that into little bits so that you've got the first page of stuff in a little screen you can play a little bit and maybe you can make that work as well.

I: So you suggest that the screen capture is coordinated with the handout?

R6: Well, not necessarily coordinated, bit just broken up into little bite sizes. So that then you do like a meaningful bit on the screen capture and then there's a logical break in the screen capture so they can go back and do that. That significant … that meaningful little bit and then go back to the screen capture and have a further look and go back and do that again. Might help when … you know if they do forget then they've got an assignment and they've got to go and refresh and… what the students do is, they sit in class and they nod seemingly intelligently and understanding, but they don't really, so if you can give them something that they can kind of play with later on.

R4: I think that logic gap is important that you're mentioning. Otherwise, it's just following instructions and reading skills. That's what we want more that that. So, yes, I like that logic gap.

R6: One thing I found about learning software that I found about myself, is that the first time I encounter new software … even when I work through an example, it's not really the most effective way of learning if it's not reinforced later on ;you actually don't learn the software. So we all learn software that way, you go and you work through an example, but all that really does, it kind of gives you an idea of how the software works, but the time when you really start learning the software is when you do something that is meaningful. You know, so if you've got an assignment, you now have to use the software to do stuff with it. That's when you really learn the software. So if they can have like just a tutorial, just to understand what variable means and how to put a textbox on the screen and you know where the … exactly how the user interface is structured kind of thing. So a bit later, when they have to go and figure stuff out, they're not completely lost. But this initial tutorial, I think you'll have to go and follow that up with giving them an actual project to go and do at home or something so they can figure stuff out.

I: A well-defined project?

R6: I wouldn't do … your whole project I would approach like this. I would start from the simple and progress. So the demonstration that you do has got to be really the simplest kind of problem that you can give them that will incorporate all the software elements. So just to show them what everything means. All the tools and icons on the software mean. But not a difficult problem because then they're going to start focusing on the problem. And they are going to get themselves lost in the problem and not focus on the software kind of thing. So I'll start with a simple problem and then perhaps progress to a bit more complex problem. And the more complex the problem becomes, the more you are going to start kind of focusing on the problem and not as much on the software. So you want to start off with them learning the software but then as you progress throughout your term as the problems become more complex your cognitive load is going to want shift towards the problem-solving and not as much as to the mastering the software and I think that's what you actually want do, you want to have them focus on the problem. I don't think you should start with a complex ill defined problem, rather just something simple just so that they can see how the software works and then go from there.

R4: On that note I was wondering if it is possible to apply the expert system in an abstract problem. Does it have to be "Yes" or "No" answers? Definite? Just something I was wondering about because we keep on simplifying our thoughts to be able to put into an expert system.

I: I think that it is important for us as a group to determine what can be modelled by an expert system and what can't. But I think we will get to that when we tackle the actual subject matter itself.

R6: And also whether the expert system has the capability to program fuzzy logic. If it hasn't got that inbuilt ability to deal with fuzzy logic that means that what ever variations of "Yes" or "No" you want you are going to have to build that in, so do you want a medium dog a little bit smaller a little bit bigger. If you want that kind of logic built into the program, if fuzzy logic is not kind of part of the inbuilt capability of the software, you are going to have to kind of have a range of pictures and ask them to click on the little bit bigger little bit small, you are going to have to program that in, which means your program itself becomes like fairly complex.

R2: Are the students themselves supposed to be able to program anything?

I: Yes, this development environment is incredibly simple, obviously for a complete novice it appears not to be but it's very, very simple, that's why I chose it as the shell.

R2: But do they have to program?

I: In broad theory, yes, but in reality it's just you have to learn the syntax and you have to know one or two syntax rules and the rest is just pure logic.

R2: That's where the problem comes in.

I: But we didn't get that far today, I would have liked us to have got that far but we didn't but …

OR: I think that in terms of the context-based critical thinking that's going to happen is going to happen when you draft you flowchart. What's nice about then moving your flowchart onto the software is you are actually going to make your assessment of the programming logic a little bit easier. Because if you assess their program logic, all you need to do is to go to the program and see if it works. Because then you know the program logic is kind of appropriate. But I think the problem-solving is going to happen on the piece of paper and not on the software. It's not going to happen when you develop the program on the computer; that's not where the critical thinking is going to happen, it's probably going to happen here. Or what will happen there s once you build your software you will see, oh but this doesn't work so that becomes also … almost a kind of Vygotskian interaction, where somebody says, "Oh, but this doesn't work" and that refers you back to revisiting your construct, and seeing OK, now we have to modify the construct here and then you take it back to some kind of independent adjudicator which is the software which shows you whether it works or not; if it works then you are happy; if it doesn't work it refers you back to your programming logic. I think that's a valuable role that the software is going to play. But in terms of the logical design I don't know whether that is going to happen. I don't know … when I work... when I get stuck on the computer I actually work it out on the computer kind of thing, so during the process of designing your flowchart you are probably going to use the software to do minor tweaks if it's a major tweak you are probably going to go back to your flowchart, to redesign your flowchart. This is the flowchart where a lot of your critical thinking is going to happen.

I: Another question I would like to ask you guys before I let you go is, are we starting in the right place? Is there another place we should be starting? Should we be giving them more of something before we get into the actual development learning the software, designing the algorithms and things?

R6: I would start with the flowcharting; consider doing that pen and paper based umm and just showing them what a problem-solving process is. Show them how to do problem-solving and then also once they understand clearly defined problem-solving move them on to ill defined problem-solving just so that they understand the problem-solving processes and from there on you can move on to a proper flowcharting of the process and from there on onto the computer. I wouldn't try to do all that in one step.

R4: On the issue of time, maybe use some of the other periods to do the planning as well, not only the lab session; I think that would be a good idea.

I: Anything else? OK, thank you very much.

Transcript of focus group interview held on 4 February 2011

R2: Okay, I'm not a programmer and I know nothing about it. What worked for me is to first put things on paper. Like it generally works for me in any event. You write things out and see how it works out there and then from there on you show us the tutorial. If it makes sense then, I think after that then the students must do it themselves, but I think the main thing is to start with a simple one like here in the beginning when it's only two options so that they can work it out. First chronologically for themselves. If they can do it here on paper, then it should be easier for them to transfer it when they see what they are doing and then they can do it themselves on the computer.

So, I think, yes, start a simple one and then add. I wrote in the first class depending on your students; have the second question added there as well. So I understood that for me, who knows nothing, it took a while to grasp what's going on. So I understand for the first one … I understood the second question … putting the second option there as well, I think for the first class, just do the basics first, and one question, and a simple algorithm and then build on that further.

I: OK, you were a little daunted the first time we spoke about programming; do you feel less so now?

R2: Yes ha ha ha!
Yes because if it makes sense here, it's still difficult for me but you can still transfer and see what you are doing there. But for me it's easier and basic and then to build on that. First get the basics under control and then carry on with the more involved things. But just, like last week, opening and doing this…

I: … too much too soon…

R2: Yes.

I: OK, thank you.
Anyone else?
OK, I'll go sequentially….

R3: Okay, I want to agree with R2. I must admit that after our last session I was a bit intimidated. Not a bit. A lot. I know nothing about programming. And I thought I was very worried because I thought the students will find it a bit daunting. I thought there was a time issue and I think you've even addressed the time issue now. Because you've broken it down into logical bits. Which follow on each other. First the paper-based, then working on your own, then you demonstrating and I could apply what I learnt and I could see the logic behind what you were doing there because I knew what the symbols stood for. You made us work through examples which showed us which question would work and what would not work. For the result we wanted in the end and I think um I just, for the first handout, just to refer back to that. Again, this was much simpler. The language was much simpler. The terminology … My perception was WOW with this terminology I'm out of my depth. But now the second time round, I thought I could try this. I can do this.

R1: What I've basically observed is that I think that your idea of using the system and involving the students to get to a higher level of thinking is a very huge topic. And I really wish you luck with it. But I can see that you have started working through it systematically and with the input that we got today from the delegates here. I'm actually interested to see how you are going to build it up from here. I agree with you, your pace must be slow. Especially if you go through the functions and make sure that they all see it and also that a guideline needs to be there if it needs to be double-checked on this. If there is something that they didn't see properly, I mean I'm sitting a little far away from here so it's just a practical thing. It's very small so it will be helpful for them to have this here. So umm …

R3: Screen print that you demonstrated will be very useful. Where you break down into a capture of the logical steps, because as you went through it now, it was a bit quick and if you did it in that way, it would've been easier to follow.

R6: Yes, I feel far more optimistic after today's session that this might work in the classroom. What I think you could do to get around the speed issue is to do something, and then stop and make them do it. Not to just let them watch through the whole presentation and then the first think they're going to forget again. So let them … .You did kind of decrease in the scaffolding quite good today kind of thing. In the same way the first one, step by step, do or show something and let them do it. Then the second one you kind of step back a little bit and you ask them, OK, what must we do next and then they must do it. Then you say, OK, do this now on your own. But you can like probably break this down into about 3 or 6 stop starts, where you do something and you say, OK now its your turn. You go and build it. And I think that might work. Other than… Yes, um, I think that should work. Now I want to make a comment, just for the record. Is just remember that when you facilitate in classroom, perhaps you go ahead of time and you train your students to be more computer literate perhaps and you give them detailed training ahead of time in a smaller group and then when you give your demonstration to the larger group you can use your expert students and call them that. To facilitate the learning process so you can tell them, okay, now you go and do it. And there are like 20 guys at the same time who need help, you can't run around doing that. So if you have your 5/6 student "assistants" that might just facilitate that process.

I: OK, thanks. That was good.

R3: OK; can I just add to that. What I found very useful when you demonstrated is that I had the opportunity to directly ask you a question, immediately, when I didn't understand what was going on. Whilst if I did it on my own, I would maybe have forgotten, but the direct interaction is good.

R5: Like R3, I really think the screen freeze is very good to use. To once you've done a step just to freeze the screen and then give a little written explanation of what you've just done. But I also think that trial and error is very important because last time I sat and I got stuck at a certain point and once you have gone through the whole process slowly, it makes sense now, but just to find the correct pitch between trial and error and doing it by themselves and giving them the information that will be tricky, I think. To find the correct balance between doing it on their own and providing them with information. Because I think if you provide them with too much information, then and without them doing it on their own, they will also feel lost. So just to marry the two, yes …

R1: The show and tell, and then the “do”. If that works together and you are there to assist and give direct feedback. It could work.

R6: I think the idea of, like, battling a bit on your own is a good one from a certain stage on. I think that if you just go and dive in and you start to figure it out, that might just become a bit demoralising. But, um, if you go and you do basic example and then you give them something that they have to try and figure out on their own, and you give them a while to play with that. Because what happens in the process of fiddling, is you then discover other things which don’t answer your question now but stay in the back of your mind for later on when you’ve got the question that needs this answer. So, to a limited extent, let them try stuff on their own for a while. For a brief while. Not too long. And then show them the right way. So that they not only learn what you teach them in class, but also that little bit extra that they discover. While they’re playing around. And that portion of learning is going to become more and more important as they become more and more advanced in their knowledge of the software. So the better they get at using the software, the better they get at discovering stuff by playing around. But that’s just, um. That’s just because, as your foundational knowledge increases, it’s easier for you to relate new stuff to it. So if you play around without having any foundational knowledge there’s nothing to make linkages to. But as you build on the foundational knowledge, it becomes easier to make new linkages to it.

I: You guys have mainly told me what worked here. What didn’t work?

R2: For us, for the students, maybe you went a little bit quickly. Just through that, but the rest I think worked and I agree with her that the soon as…

because I'm going to forget if I'm not going to do it now. I will forget until the next time. It's like any computer program. If you are going to work with it, you won't forget. So if they can, after each step just do it and then they should be fine.

I: Okay, any one else?

R6: And R5 is going to facilitate in the classroom. Because you are clever to facilitate to beginners because I don't think you remember when you didn't know anything. So you're still making assumptions about like certain terms. For example, you know what this term means. And you just use the term and you carry on, but if you have somebody who has no knowledge about the software, writing the manual or presenting the class, you gonna get a better match between the facilitator's language and the students' knowledge of the software itself. Because they're gonna phrase their explanation not in terms of technical terms, but they're gonna phrase it in terms of they're understanding of what has to happen. So they're gonna describe what a variable is without using the term variable. You know? You just assume everybody knows what a variable is. Kinda thing. So that will be a good match, I think.

I: Anyone else?
So do you think we've reached a point in our design where we can assume we have covered the students learning the software and understanding the expert system logic?

R3: I definitely think so because everything today was very useful.

I: And the students will be able to deal with what we've done, today?

R3: I definitely think so …

R6: I think if you take what you've learnt today just build that into your lesson, if you want to call it that. It might work. You might want to demo it onto a smaller group, just do a little bit of a pilot and check and make sure and see what you learn from that experience. But I think that you are kind of 80% of the way there.

I: All right. Thanks everyone.

Transcript of focus group interview held on 9 February 2011

R3: First off I think the fact that you gave us paper-based questions so that we had something in front of us to work with was a good idea. I think that R2 suggested that you should not hand out everything at the same time, so that there are logical gaps again. And I think that the questions could just be more specific and if you have a forum where you have face to face interaction with the students while they work that terminology should be explained and that feedback should be given after each logical gap.

I: When you say terminology, what terminology?

R3: Terminology like the word *context*, like the word *situations*, things like that. The assumption is maybe that they would know what it means, but I don't think we can make that assumption.

R2: I think what you can do there is, instead of just explaining everything ask them what their understanding is of the concepts before you start. And then break it up. And give them an example maybe of the communication situation if you want to, I know you said that you didn't, but make it something different than the context that you have there, like a corporate environment, make it something different that they can't use. That will give them an idea of along which lines they should think, I know you want them to struggle but they should have an idea of where to start otherwise they might not know what to do. Another thing that I thought of is in the end everybody, every student is going to develop his or her own expert system so what you might find in groups of students who sit like this that they don't want to speak or that they are used to getting everything and now they have to think for themselves so that might, I don't know whether it is relevant, but it might be a problem in a group environment that one student is the bright spark and does everything and in the end when they have to develop their own then they still struggle.

I: OK, how do I involve them?

R2: I don't know.

I: So you anticipate it being a problem, though?

R2: I'm just thinking that it might be, but if the groups are small enough then it shouldn't be, you know two or three then you know you can't just sit and say nothing, yes.

R1: I just want to add to what we are saying. I think that it is important that before they do this whole exercise that you paint the picture a bit clearer. You can give them scenarios as example, you don't have to say this is exactly how I want it but it gives them a clear direction of what is expected from them, umm, I mean it helps to give them more guidelines, I mean you don't have to give them the recipe, they have to figure out the recipe for themselves here. Umm, and even if you look at the wording here it can be confusing, so make sure that what you have written there is clearer, maybe here and there a word but then before you … They know what you are wanting to achieve instead of you telling them what you want them to achieve at the end they have to bring in their input, they have to trust in their creativity that they are going to create something that hasn't been before. You know something like that. For me it's a bit more guiding, and then when you come to this part where they have to develop the flow diagram the moment that they get there the beginning must be clear otherwise they will not be able to do this.

R6: Umm… . We spoke earlier about your need to explain what the different components actually mean if you talk about context what do you mean, if you talk about audience what do you mean by audience, so perhaps just remember when you get to the section of the questionnaire that deals with *context* that you just step back a little bit and explain exactly what you mean by *context* and when you get to *audience* just explain a little bit further. That's the one thing, the other thing I want to say and, umm, from a research design point of view from a little bit with an ethical slant, what you are saying is very true about groups, um, that everybody doesn't participate in groups and for varying reasons. Some people just don't like working; some people just don't like groups so I'm one of those persons, if you put me in a group I … and depending also on who my colleagues in the group are. If you want me to keep dead quiet put me in a group with an opinionated extrovert and I will not contribute at all in that group. I'll let the group go down knowing that they will go down, knowing that they make a mistake but I won't contribute. So groups, I know people think that groups are the most wonderful thing to use in class group because it saves them work or whatever it is, umm, it's not fair towards introverts at all. Umm. so maybe think about a way in which you can deal with people who like working in groups and those that don't like working in groups. Having said that, even introverts need to be able to work in groups so do it sometimes but not always. Umm, I was very fortunate with Johannes, he used to do that with me, he knew I hated these things so sometimes he would just force me to work in a group and sometimes he said, “No, you don’t have to”. Umm, just as a suggestion, groups for some people are just very, very, very threatening and it will actually hinder the learning for some of them; some of them will be able to work around that, might be capable of taking this home or working this stuff out on their own, in their own time, but some of them won’t be able to. So groups are not always a nice place for some people.

R4: I was just thinking one thing as well, perhaps a good idea … just thinking about it now, is to maybe have a brainstorming session about different communication contexts in little groups, umm, but just to create the context of what to expect in the class and then getting feedback from all the groups; I think that then you already have something to work with and then you move into this question, three situations in which communication can take place; then already I think …

R1: Let them role play a situation … that they would role play a kind of situation and then you would say right, you did that now write it down, …what are the components, who are the role players? It might give them a bit more experience.

I: Might be a bit time-consuming?

R1: You can give them five minutes, ten minutes. Think about it and do it, they are very good at role-playing.

Transcript of focus group interview held on 16 February 2011

I: Perceptions of what we have been up to today?

R3: Umm, I think the face to face interaction worked very well. I think the way that we progressed with facilitation through the concepts worked very well. The segmented way that we did this and the video clips the visual really I think will draw in the students and the real- life situations, the complex real -life situations would help them a lot. I wouldn't go and give them more paper work, I would go … do the basic concepts that you did multiple choice questions etc. and then do the rest segmented, umm, with all the other concepts face to face based on the video clips again.

R4: I just want to say something there. I think what we did today worked very well but I think what we must keep in consideration as well is that we are going to sit in a class of seventy students and there is going to be a lot of … This worked well because there was a lot of feedback and discussion; now there are going to be seventy people in a class, so this again, there will have to be small groups and then feedback from the groups, and then you will have unhappy people like R6 in the group. So I think we must just think about that as well.

I: OK, so how do we overcome that, big classes, what do we do?

R4: Well, as I said, maybe small groups and then feedback from the groups. But it's not going to be as streamlined as it was today. And then what also worked well today … or maybe we should swop the two exercises from last week and this week. Do this and then go on to do maybe one example of their own, their own scenario. Exactly like last week but maybe one scenario. Because then they will know what it's all about and then move on to their own flow-diagram. That can work the two exercises together.

I: So we shouldn't abandon last week's exercises but we should maybe just incorporate them into this week's.

R4: I don't think so; and maybe just one scenario.

R1: I agree with you, what we missed last time was the step in-between and this lesson was the step in-between. From the beginning when you explained the expert systems and then the CMAPP… so it was very good and … giving some … something more sound that's not completely abstract so I think it's a good idea.

R6: Umm, the thing that I liked particularly, I like that you take context and you work through an example in detail, like we did today and you go back to the video clips and we start discussing some stuff in the video clips. And then if you guide that discussion towards, let's say product as a concept, you start talking about you know what's on the board there what … you know discuss about … without telling people that they are discussing product, you just start leading some kind of discussion on what the product is. And once they have discussed that a little bit and explored and got them to what you really want them to understand about product then you can step back and summarise for them. So you see … So when you talk about a product this is what we mean by it and you can summarise then what they have said. And you can move through … you can use different video clips to do that, you can use one video clip for product and one video clip for purpose, for example. So you take the next video clip an you start discussing the purpose without telling them that that's what you are doing and you take a step back and you summarise and you say OK, in that video clip this was the purpose so that they understand these things that they had running around in their minds now, then that goes to purpose. That's a good way of them kind of analysing the situation first and then reducing all that discussion down into a formation of a concept. That kind of was a nifty trick for me, yes, I enjoyed that.

R5: Yes, I also like the paper-based exercise because scaffolding was provided by first starting with multiple choice, just opinions and then later they had to express themselves in writing and then in paragraph form as well. So I think that it was well structured and scaffolded and also visually … real visual … the students will have real visual interaction with the videos that you are going to show and based on the videos they can answer these questions. So I think that was quite good.

I: Anything else? Umm, getting from a conceptual understanding to graphically representing their understanding in a flow-diagram, what is an effective way of doing that?

R3: Well, the way that you demonstrated it here facilitating, sort of another brainstorming session but not doing a mind map, doing the flowchart immediately. That would bridge the gap for me back again to the flowchart and show me what would be the end product, that you would expect from me, without telling me what to do and what to put in specifically. So I didn't mind that way.

I: Did that work for you?

R3: It worked well for me, the flowchart immediately.

I: Can you think of a better way of doing it?

R3: No, I don't think so.

R1: I would suggest that... depending on the need of the student or maybe his way of expression that they can either do the flowchart or then write it out in natural language which … it could be a preference … you can give them the opportunity to choose between the two, umm, and there might be somebody that is most comfortable with doing the flowchart and then writing it out so before he gets to the expert system then he knows that there is nothing in-between that I left out.

I: OK, anybody else?

R6: Following on what I said earlier, if you could do a video clip and have them discuss a concept, like *purpose* for example, and then once you have summarised and told them this is what *purpose* is about and then move directly onto flowcharting purpose, then it keeps everything together and it actually gives them a good understanding of what it is when you talk about a flowchart; what it is that you are trying to achieve with them. So I think what you did there was quite a good way of doing that.

I: What was the word you used earlier?

R6: Contiguity, that means touching.

I: Did my representing the understanding directly in a flowchart work for you?

R4: I think it worked well and then again moving into them modelling their own diagram based on their own scenario, like last week's exercise perhaps. It would work well after you have done that example. And they are still not going to model what you have done there; they will still have to think about it themselves. It will work.

R5: I think that it links nicely, theory with practice, the flowchart. Because now they did the theory, all these concepts and now they must just represent it practically in an expert system, and, umm, I think this provides a good link between the theory and the practice.

I: So it worked the way I did it there?

R5: Yes, yes.

I: Anyone got anything else to add?

R2: I don't know what they said but the visual clips were very interesting, that's always interesting to students to have something like that and not everything paper-based. So I think that will be a good starting point or point of departure for the students. I don't think it was difficult, we used some terminology that we know but I think the students will be able to, mm, describe what they know or the situations or their ideas.

I: Anyone got anything else to say?

R6: Umm, perhaps consider when you do this paper-based exercise, to do a clip and then make them answer the questions on it, do a clip and make them answer the questions on it because it keeps the content of the video fresh in their minds as well while they are busy do that. Umm, make sure that in the room where you are playing the videos that the students can actually hear what the guys are saying in the video clips. Because when I looked at the video clips I could kind of hear a voice and I could hear that they were speaking but I couldn't actually hear the voice and that's because of the sound quality in the room. It's not the sound quality of the clip; it's the sound quality of the room. So for this to really isolate that which they are supposed to see they need to be able to hear as well as if they were sitting in front of a screen. They need to have that kind of perception of what's going on on the screen. So just make sure about that. OK, I mentioned that with product, when I read about product I know what product is but there is a bit of ambiguity in the way in which they describe it. They say the product is the physical, kind of thing on which the message is conveyed in the end. And if you say the message is the paper or the blackboard or whatever and you refer … and you say the product is the paper and you show them the paper like that, they are going to think that the product is the naked paper whereas the product is really that side of the paper. You see what I mean, the product is really the whole thing with the words on it and the right font and the tone of voice and everything. That is the product, so you must just make sure that they understand that when you talk about the product you are not talking about the medium, you are talking about the whole kind of physical representation of everything. Umm, and I need to still think about the flowcharting thing and weather that in the end … I'm looking at … that's why asked you to mention your research problem again because your research problem is not really related to the CMAPP concept, its related to, umm, to the internal construction of a concept so, umm, I'm looking at it from a different point of view, I'm thinking what's going to happen, what's going to work for the students to understand CMAPP in the classroom which is kind of what you need to do in the classroom but for the purpose of your study that's not what you are trying … that's not the focus of your study. Umm, so for the purposes of your study I think the flowchart will probably work. For the purpose of them understanding the concept it might not be the best way for them to understanding the concept. So that's why I say the flowchart might obscure their understanding but then again I've got my lecturer hat on and thinking about what's going to make the students understand best. So I need to get my head around your research problem still and the flowcharting and the construction of the intelligent system. I need to think about that still.

I: Actually I don't think that my research problem and the instructional aim of the lesson are in conflict with each other.

R6: It will work; I'm just saying that I don't know whether it is the best way.

I: What would be a better way?

R6: That's what I'm saying, I need to think. I will. I Promise, I will.

I: Maybe once we have worked through the whole process you will have a clearer understanding of what you want to do.

R6: Ja, ja.

I: Anything else? OK, thanks very much.

Transcript of focus group interview held on 18 February 2011

I: Impressions of what we have been up to today?

R6: Umm, nice I think the way of getting to the logical way of flowcharting something like context … It was a nifty idea to do it this way round, I think it might work well, … umm.

I: Before you carry on, why do you say so?

R6: Because what you are doing is you are going through the thought process that they need to follow to get to the questions that they need to ask to get to the flowchart without them knowing that that's what they are busy doing. And so in the end when you get to … that might become apparent to them what you are busy doing but, umm, it's going to kind of help them to understand … without asking them to give me this and this and this you guide them through a process which is the process that they need to follow to get this and this and this. So they actually get some practice at doing that without them knowing … without them being intimidated by this vague question that you are putting to them … so, yes, it's a good way of concretising, umm, the process that you want from them. So yes, I think this worked well, this approach. Ah the one … A couple of things that I made notes on, the one thing, when you show them skits, umm, perhaps you should think about whether you want to use humorous skits or not. Because what happens, you've got dual signalling, if I can call it that, in a humorous skit. So this is … L\like a serious thing going on there, there's a business meeting, which is serious but you've got subtexts because of the humorous nature of the skit that you are doing which is perhaps confusing when determining the tone ... you know. For us that was difficult when we had to ask you the questions because … umm, and also I think for you to answer those questions because it's a meeting but it's also funny... you know … how do you answer that question. So perhaps you should take something like the rock concert or the interview where there is just kind of … there's no subtext in the video. Perhaps just think about that. Umm, the other one I was going to give you some homework. To do this in natural language and see what you can come up with. And then, let me say this for the record. Your facilitators need to be trained for constructivist interaction. That's not something that comes naturally. A story that I want to tell, when we worked with Johannes, that's one of the stories he told us is that he went to a school to try and get them to start working constructivistly, umm, and he said that the first thing that he needed to do was to actually train the facilitators how to facilitate a constructivist learning environment. That's not something that they learn naturally. Naturally you want to stand here and you want to lecture down to people. So you need to get used to this constructivist environment where the learning belongs to you constructors not to your facilitator. And when you have a dead spot you need to trust that dead spot, you need to know that that's part of the process you know and how to facilitate through that perhaps. But, umm, if these guys aren't trained and they walk in there and they encounter a dead spot the natural reaction is to start lecturing, umm, so they need to rained on how to facilitate in that kind of environment. I know that we walk into a classroom and we say this is the year that we are going to do it right and you give them homework and you say *Go and read this* and you come back to class and you just ask them a question; you ask them the first question and nobody answers you and you wait for a while and there is this unnatural pause and then you start talking and there you have lost the plot. That's something that they need to learn how to do and once that happens … that's just the first. Now you've got a group of learners who've never really worked in that way, so they need to become familiar with a constructivist learning environment, they need to overcome their natural resistance to speaking up in a group and to participate because you can't construct knowledge, especially in a social constructivist paradigm, you can't derive group meaning if nobody is speaking. So you need to do some training beforehand before this is going to work, I think.

I: Thanks.

R3: Umm OK, I think the … again, as with the previous session, the interaction that you facilitated worked very well, umm, the clips that you showed, on a level of interest to the students, would I think involve the students very well. I think it worked extremely well, but I want to agree with what R6 said, the facilitators in class will have to be very invested in this and you will have to train them. Umm, and then I think you bridged the gap very well today, jumping from the conceptual learning to physical manifestation in the flowchart. For me today there wasn't that moment of hesitation of what should I do next, it flowed naturally and that worked well.

I: Just the same question that I asked R6 just now, why did it work well?

R3: Umm, I think it was a natural progression into … because you have already now drafted the questions and you don't have to now go sit and think, if I do this flowchart now what would be the best question to ask, what would … to develop questions, because now the questions are there already and, umm, just one more thing, I think using the newspapers, using the clips, the real-life environment, I think that worked very well. It's not something separated from what they do every day, they see that this is real life, this is how it is and they can work through this. It's not a separate concept that they have to grasp.

I: OK, thank you.

R2: I also agree with what R6 and R3 said. For a while I thought when it came to the questions that we should go to the who, what, where, why but that's just and how I want to teach the students. But that's not what we, what you want to do. Its best to let them come up with questions and then, maybe from that they can see, OK, if I ask this question then I can answer, you know, who is involved is actually the relationship, which can encompass many things. But I think maybe for students to make it more basic is to have specific questions, like, what is the relationship? And what is the setting? To make it more concrete, yes for them to learn. I also agree with them about the facilitators and maybe your first class or the first thing, when they introduce it you should maybe be there just to check that they know what is going on and they are doing what they are supposed to do. Otherwise you are going to, umm, leave it all in their hands and then in the end maybe get some feedback or information that this is not quite what you were hoping for, I think.

I: How do I … The idea behind today was to bridge the gap between a conceptual understanding and a representation of that understanding. How do I improve this?

R2: It was natural for me … when you had the questions … remember they have seen all of this … asking the questions and they know what those shapes mean now so now when you put the question there then obviously they have to think of all the different settings; for example, and then take one and what's involved there, that is logical to me. It's logical also because we have that background and you have done that in the beginning, showing how this chart works, that was good. If you haven't done that and you get this now then I would have been lost.

I: So you don't see any obvious room for improvement at this stage?

R3: For me it was actually, I must say, in one of the previous sessions, where we had to make that jump, I had to readjust my mind and OK, now we are going to the flowchart, what now. What question is first? What should happen now? And with the questions already developed today, you could basically just apply it to the flowchart and there were not so many things that you had to consider so that it wasn't as daunting a task. There were things that you had to think about but because you already had those questions it just made that gap more digestible and easier to work with.

I: OK, thanks.

R6: I think that when you start drawing you flowchart, your question to us was, "Which question would you ask first?" But because there is not real correct place to start at, perhaps you should say, with which question do you want to start? Because that, umm, will tell them that the order of the questions … now this is difficult because as you said sometimes some questions do lead on to the other, umm, but unless that is like really, really apparent from the questions that you would need to ask this question first. If there are five questions and they are all equally important, it doesn't really matter where you start; I would ask them, "Where do you want to start from?" so that they understand that they can start from any place and the way in which they do it is not going to be incorrect if you start doing it at a different place. Umm, so that thing about that there are many different ways of representing that because your learners … especially if they are like younger learners they are going to want to copy what you are doing. So if you don't make that very clear you are going to see all of your flowcharts looking like this and you … I don't have to tell you that. Umm, the other thing that I think you … that we can do to … starting from here is really where the learning is going to start taking place, when we send them back in their groups to go and develop a flowchart on their own. Umm, because that's where they are going to start negotiating amongst themselves to get a flowchart on the ground. So I think that's really where the understanding is going to start, when they start interacting with each other and in that process I think the first couple of times, you as facilitator, are actually going to learn a lot about how to facilitate this kind of thing. Because once you get the first representations back you are going to start understanding how you students understand stuff. So that will tell you what they are doing right and what, in inverted commas, what they are doing wrong, in inverted commas. And umm, so then you will be able to tell them, this thing that you are doing here just think about it this way. So your facilitation is also going to be responsive to what they come up with. But I think that it is important to, from here on, to take that to give it to groups to do some work on their own, to really get to grips with what this process is. I think what happens in our little small group is we always kind of … we don't have time to sit down and really work out what it is that we need to do and that's part of the problem why we don't really get to grips with what I want. But if you go away and you know that by Tuesday you have to come up with something, we are going to actually negotiate a common understanding. That will aid the learning process I think.

I: Anything else? Thanks again.

Transcript of focus group interview held on 23 February 2011

R6: One quick observation is that the nice thing about building an expert system like that is that it is quite easy to assess, I don't know whether that is the right word, to assess whether their logic is valid. Because if you look at the screen when you do the screen preview kind of thing, they have got two conditions selected and they have got a display and if those things match up logically it means everything else must be in place. It doesn't matter how they got to the answer; you are just interested that they get to a valid answer. So what you can do is to go around and have a look at everybody's, you know, thingy, what they selected and what the display is and you know whether they have done it right or not. So it is a nice way of …. Remember we spoke about you having a jig and you take something and you put it in a jig and if it fits then it works, so this is kind of a jig for their understanding. If that works then their internal representation … .You don't necessarily know what the representation is but you know it's valid because it comes up with the "right answer ".

R1: OK, what I liked about this is the approach that we worked together as a group and that we kind of reminded each other and that we learnt from each other. So it was kind of a socio-constructivist approach here. And I think even if we have different learning styles and ways of remembering, it worked because we had these visuals we had the auditory, we had the interaction and to create and expert system like that is a challenge but working together, it works.

I: Good, thanks.

R4: To build on that, so maybe we should think about are they going work in pairs in small groups physically in the labs, that's something we should think about, because it worked well now when we worked in a group together. And I was also thinking, in a lab, will the students also be able to see what you do on the computer on their own computers or will there be one overhead, because that's not going to be practical, in those huge labs.

R1: It will be in steps, the first one everybody does together with the lecturer so they see it on the screen like we did now; the second time you can make groups.

R6: I don't know whether you have NetOp in there, the facilitator can control the screen of the students. So you can physically take control of the screen and show them what you see on their screens.

R4: We are going to need that, do we have that?

R6: They ... it used to be installed in the labs at Sosh.

I: But guys, what I am proposing is actually presenting exactly what we did now to the students; they are not in groups yet, it is as a class. Once we have got a flow diagram representing their groups understanding of context, I want to do exactly what we did now. In other words, let's develop the expert system as a class and invite volunteers from the class to come and do it while the audience shouts instruction, support, and guidance to those persons. Your impressions of that?

R6: This works better if you get the class to do something. It's like if you drive in a car to a certain destination, if you are the guy driving you get to know the rout to that destination; if you are not driving, you are just a passenger, you get to know more or less where it is but you don't know the road. And it's the same kind of thing here. I found that when I was looking I kind of had an idea but as soon as you sit and do something yourself then you get the proper idea.

I: Is this step necessary? What I did now, is it necessary? Because remember, they are going to get a lot of practice doing it on their own. It's just that I need to give them a little bit of scaffolding.

R6: For us today I think that it was necessary because we hadn't done it for a while and then we didn't really know what we were doing. So in today's groups it was necessary.

I: And for the students?

R6: For students if they did the previous step, remember when we learnt the software, if they had mastered it then, today might not have been that necessary and you will be able to pick this up when you start doing this and the students can immediately tell you what to do next; then you will know that they are on the same page, if they are not ….

R4: I think that this step is going to be crucial, because time is going to be a problem.

I: My thinking behind this is for it to be some sort of consolidation exercise. Because remember, we have talked them through the process of asking questions to gain a conceptual understanding, taking that conceptual understanding, representing it using a flow-diagram and then the consolidation will be actually, the group … because remember, we have all worked in a group up till this point, actually developing the expert system. Is it necessary?

R6: Its not difficult stuff, so if they had gone through the software earlier by this stage, if we get together as a group and do this consolidation stage, umm its going to refresh their memories pretty soon if they have forgotten some stuff. So I think if their prior knowledge is adequate; then, at this stage you won't have to work individually again like we did today. Unfortunately the only time that you are going to know whether they know enough is when you start doing this. Because if you start doing this and you don't get answers or you get the wrong kind of answers, then you will know that they don't have the prior knowledge that you assume.

R1: If they haven't had the opportunity to work on this then, umm, they might not really have that pre-knowledge. This step that we did today is the first time that we, that each one of us had the opportunity to sit and work on it. So they might have an idea but to really do it as you were saying ….

R6: Yes, we did work on this earlier, I don't know if you were here that day. But there is an assumption that during that previous phase when they learnt the software that they actually will learn the software, so at that stage they will have to work on a kind of individual basis.

I: OK, can I just round this off? Is this a good way to consolidate the learning at this point? Yes or no?

R6: Yes, I think so.

R1: Yes.

R5: Yes.

Second focus group session

I: We have got to the point now where we have to present the students with an ill structured problem, because that after all, is the point to this whole thing is that they can represent their understanding of a concept by developing an expert system. How do we present the ill structured problem to the students?

R5: I think by giving them a scenario because that will be … the problem will be situated within a real life scenario and it will give them a little bit of information or structure. Although it's going to be ill-defined it will give them a little bit of structure just to provide scaffolding for them to start with their designing the expert system. So I think scenario, they must be presented with a scenario.

I: OK. Any ideas on the nature of that scenario?

R5: I think like we usually do in tests, in the form of a written paragraph, in written form.

R1: Maybe a problem.

R4: Or perhaps a video again, like we were doing, the communication scenario.

I: All right. How would the video represent a problem that they would need to solve?

R4: Well, they would need to … Yes; I see what you are saying so you have to think about the communication in that scenario but ….

R5: Maybe a scenario on a video that illustrates a conflict situation that's a problem that they would have to solve, a conflict situation in an office environment for instance.

R6: I think scenario I think is good; it can be millions of different scenarios so pick one. I think that when you describe your scenario you must have five components kind of covered in the scenario and the il-definedness of the scenario depends on how much information you give to them when you describe the scenario. So you can describe that scenario in the greatest of detail and everybody will come up with the same kind of answer. But if you leave some information out … the more information you leave out the more ill defined your problem becomes. Umm, and then finally, what I would want them to do, after they have done the intelligent system that is play stuff, they must actually turn that into a product and you assess the product for whether it's covering the five components. Because if you see the five components that they render, that's where you are going to see whether they get the whole thing. Umm, in terms of what do you do with the ill definedness, how do you get a clarification of the blur, that's where I was talking about perhaps having a boss and a secretary or a .. Where a boss gives a scenario to a secretary and she has got to come up with, ultimately, with a letter that she writes to a troubled customer or something like that. So ultimately the output of the whole exercise is the letter that the secretary is going to write and she writes something and if there is information that she needs for her to write the letter she has got to refer back to the boss to get more clarification about that. Umm so yes, I think that kind of scenario where you have customer client superior subordinate kind of thing, where somebody gives a problem to somebody else but this … the amount of information that you have in that instruction is limited depending on how vaguely you want to define your problem and then you tell your student, your secretary that if there is anything that she needs more, to know more, she must come and ask you direct questions and you will answer direct questions umm, so in that context maybe you should have yourself as the boss and groups of students as secretaries.

I: What do you guys feel about that, bearing in mind that the aim is to get them to develop and expert system not necessarily to get them to write a letter or produce some sort of product? So my feeling is that the scenario should lead to the production of an expert system not necessarily a letter, so the scenario would have to be something along the lines of "You work in a company that has communication problems. Develop an expert system that would guide them to become better communicators." That is the sort of scenario I had in mind. What do you guys feel about that?

R5: If you ill define it like that … maybe just to show them a video or two in which they can get more information. For instance, you have communication problems within the company but then, for instance, you show them two scenarios in the video what happens in a meeting and what happens when they are working in an office environment because I think that they will get a lot of hints from that in order to help them construct their expert system. So, in writing ill defined but when showing them the videos showing them or giving them more information that they can use. Not clear cut information; they must still look for it so it's still ill defined but they must look for it in the video, read between the lines so to speak.

I: Anything else?

R6: I'm thinking, if you select the correct video, let's say for example you've got a video of a board meeting and ultimately the kind of product that you want out of that is a set of minutes, let's say for argument's sake, then you tell your students OK, here is a board meeting; go and write the minutes of it, develop an expert system that would help you write the minutes for the board meeting. So then they look at the video and they can look at it over and over and over; that becomes your source of reference for information. The problem is ill defined. If they need more information they can go back to the video as many times as they want and get more information from that and then ultimately they can develop their expert system based on their understanding of what happened at that meeting. And I'm saying a meeting, you can use something else, it's just the first thing that came to mind.

R4: I like the idea, just looking at the scenario and thinking your expert system in the end could tell you how communication could have been done better. That's your main goal. Does that make sense? So maybe that can be your approach and even though again before starting with the actual exercise brainstorm in what way in that specific scenario could communication have been done better. How can you improve communication in that specific scenario, and that's something; that can be a starting point of the expert system.

R1: I agree with him because I think brainstorming is a very good part. I'm back with a socio constructivist approach. If you would have one scenario, say a video clip and then discuss it in say a brainstorming session and say, what the options could be out of this. How can we create an expert system out of this situation? Discuss it with each other and learn from each other and the next one they have to do themselves.

R5: Almost like a test run.

R1: Yes, but as a group, learn from each other and then ….

I: What do you guys feel about that?

R4: What you can also do is use the same scenario and then they on their own from that point onwards.

I: What role does the facilitator play in this whole process?

R5: Provides the scenarios, but how far should he be involved? But that's why think that it should also be put in writing; the problem statement should be put in writing and as a support you show a video. Maybe … I think … it mustn't be taught or lectured, it must be in the background, and the lecturer must be in the background. So I think scaffolding must be supported by the written instructions and by the video.

R6: I think that the right word is to scaffold the learning, so if they ask you a question you ask them a question back, so you don't want to give them direct answers to questions kind of thing but you want to guide them in the right direction. So you don't want to be directive but you want to elicit thought; so if they ask you a question you don't tell them to go and do it like this, you tell them about different things that they should consider for themselves, so it's a provider of scaffolding not a … .

R4: And just to make sure that they have covered all the elements in the communication process and that they have only focused on the setting, for example.

I: How? How do the facilitators make sure …?

R4: Well, let's say for example, in the brainstorming session by asking ... let's say … not talking about barriers ... they didn't cover that ... by asking questions, like triggering their minds.

I: Remember, we have moved passed the brainstorming; they are actually developing their expert systems. What role must the facilitator now now?

R1: He would be like a resource, so if they would get stuck they would ask him questions but he doesn't hover around them and check that they are doing it correctly, so they go to him if there is something that they are not quite sure about, kind of supporting them if they need him.

R6: The thing that I hear you say often and that you must be careful about, you say that when you do constructivism that there is no right answer and that's actually only partly true. So if you want them to have a conceptual understanding of CMAPP the elements that they come up with in their intelligent system have to vaguely resemble those five components of CMAPP and so when you facilitate you have to make sure that they have got something in their model that says *contex*t; they can use another word for it, that's fine but they must have something that says *context* and they must have something that says *product* and they must have something that says *audience* or what ever the case may be, umm, because if you don't do that … if you don't make sure that that happens, they can come up with a model that is kind of a incomplete model and in our environment we have a responsibility to actually convey, umm, a proper model. So, it's good enough to say whatever they understand is valid but not in our environment; in our environment there are certain outcomes that need to be achieved. So you need to make sure exactly what the outcomes are that you want from this exercise.

I: Should that not be implied in the ill structured problem? The outcome should be implied in the ill structured problem?

R6: The information and stuff should be given in it, it's just that you have got to make sure that they pick it up; they might not pick up that ….

I: OK, so it is the facilitator's role to ensure that the ill structured problem is adhered to? Or solved?

R6: But they get all the information from the ill structured problem that they need to get from it, so you need to guide them in that direction.

R4: I don't know whether it's too much information but maybe after one or two weeks when they have been working on their expert systems to make a list and ask whether they have considered these elements in your expert system. I don't know whether it's too much information.

I: So just do an interim development meeting or assessment?

R6: And then if you see there are some shortcomings you do you're …, what about this, what about this question; move them in the right direction.

I: And how do we divide them into groups? How do I tackle this issue?

R4: It usually happens naturally, in pairs or we must decide now will it be pairs or groups of three or four but usually that's not a problem.

R1: Doesn't it depend on how many computers you have? Umm, how many can work on one computer? If you want to develop and expert system you need a computer, so ….

R4: It would be impractical having four people sitting ….

I: What I am really asking is, do we combine different expertise levels? If so, how?

R6: I like having balanced groups, because if you don't have balanced groups in terms of mixed capabilities kind of thing you get kind of a skewedness in the learning that takes place. So perhaps what you can do, just as a suggestion for every group you define four roles. So there is a scribe and there is a whatever. So what you can do is, depending on the capabilities in the class, lets say if you got … I don't know if you want to use previous test scores or something like that, stratify your class into four strata and then the bottom quarter you make them all scribes and the second quarter you make them … umm … tea carriers, whatever the roles are that you want to define. And then what you do is, you say OK, we have got twenty groups that are going to do this, you can select in what group you want to be but there has got to be a scribe and this and a this … in every group. So they can select in a way, which gives the freedom of choice which is a nice adult learning principle. They get some choice, but you have a mix of some talent, ability or whatever in the different groups. So there is some degree of free choice as to what group they belong to but because of the way that you stratified you roles within the groups you are going to get a fair spread of ability within the different groups. It doesn't have to be on the basis of previous scores; it can be on the basis of, I don't know looks.

I: What about on the basis of self-assessment? How would you rate your understanding of CourLab? And then say those that scored one over there, those that scored two over there, those that scored three over there, self-assessment, divide them like that?

R4: And you put all the ones and the fours together, something like that?

I: That sort of thing, combine different levels of ability determined by their own assessment. Something to think about.

R6: Sorry, I've got problems more than answers. The problem with self-assessment, you need to standardise the self-assessment because what is excellent for one person is very poor for another person.

I: The reason why I said that was because, even in this small group, here we had people like R2 for example who lacks confidence completely and she would rate herself right at the bottom and then we have got people like yourself who have a good grasp of this and I think that self-assessment would be very accurate, so its maybe worth a try.

R6: It's difficult because if I have to rate myself according to other members of the group; that's one thing. If I have to rate myself according to the software I'm going to rate myself low. That's the problem with that, because normally the guy who knows a lot knows how little he knows so you down rate yourself and the person who doesn't know a lot knows everything that he knows. You get kind of that skewedness in self-assessment often, so if you don't standardise it you get funny things coming out.

I: But do you think that it's worth a look?

R6: You can explore it, ja.

I: All right, how do we get them to compare and contrast their understanding? Remember, we have divided them into groups now, now to compare and contrast, any ideas in this regard?

R1: After they have constructed their expert system, they will be presenting it to the class … are you talking about different groups now that are contrasting each other?

I: What I'm trying to get at is how do they show each other what they have done?

R1: I think that it would be good to present to the others what they have done and explain what their thinking was.

I: OK, any other ideas?

R6: We used to do home groups and specialised groups, so you get … you get two sets of groups. So to every specialist group you give one component to go and explore and then you reconstitute. So they work in different groups on the components and then they come into the home groups and hey share their understanding and in that way you do have that where ….

R1: Would that not be a very long process? I know what you are talking about, I've tried that, I've done that but it takes very long. It's a process where each one of them becomes experts, they have worked out their expert system, their way of thinking, now all of those have to move into other groups, so it's this whole process where you have got these other groups on the side and it's say in the middle. So it takes ….

I: I understand what you are saying about the specialist groups, but what concerns me is that the integrated nature of communication will be lost at some point when we segment it too distinctly. How about this for an idea? What, if after a period of development, I combine groups and they take the best of each and they come up with one. What do you all think of this concept?

R6: You know, like at conferences and work sessions when you do like breakaway groups and people come back and they do report backs. So if you have your different groups go and construct models, come back and report back to the bigger group, but then importantly, they have to go back to their groups and redefine their understanding. Because otherwise you never concretise that the compare and contrast thing does not concretise unless they go back and look at their models and see what they have learnt in the bigger group effects what their understanding is.

I: How do you all feel about that?

R5: Refining the problem.

R6: Perhaps an easier way of doing it rather than a home group specialist group thing because the numbers in the class will affect how the groups work.

I: And also one of the concepts that they need to understand when it comes to CMAPP is that the elements cannot stand alone. All right, my last question is, "How do we evaluate what they have done? What process can we put in place that would allow us to assess, monitor, and evaluate what they have done?"

R6: That's why I came up with the idea that after they have developed the expert system that they actually have to produce the product and you asses the product because that product is going to give you the best representation of their internal model.

R1: The problem with that is that there might be steps ahead of this that they did manage, so if you look at only the end product and you say that the end product is now … a hundred percent … how can I assess that you just maybe assessed one of the components to get to the end product and he gets zero out of ten. I think that there needs to be a rubric that comes from the beginning through till the end certain sections, they are either competent or incompetent.

R5: Continuous evaluation.

R1: Yes.

I: My concern regarding that is them being able to produce the perfect minutes of a meeting or the perfect letter does not indicate that they have a conceptual understanding of the model; it just means that they have some understanding of what a good presentation should look like, or a good letter should look like. It doesn't really say to me that they have considered all the elements involved in the process.

R6: Does it matter?

I: I feel it does, because they may have got that information, they may have arrived at those templates from some other source. What about if we get the different groups to evaluate each other? What model can we develop in that regard? You know, based on the ill structured problem, have they arrived at a decent solution? I know that our agenda is to get them to write the perfect letter or to present the perfect presentation but I think that that is thinking very narrowly, I think that it is a conceptual understanding that we are trying to achieve here. So I think if we get them to assess each other's models or each other's expert system in relation to the ill structured problem that we presented to them. What are your thoughts in this regard?

R6: Umm, I think it is important ahead of time to give them an assessment rubric, to tell them what it is that you are looking for and if you make the group self-assess or peer assess … as long as they assess in terms of your initial rubric. And perhaps you want to calibrate that just a little bit to make sure that they don't just give everybody a hundred percent kind of thing.

R5: What about if we let the group just write a test at the end of all this?

R1: I think that more leaning takes place when interactivity takes place and discussion takes place.

I: Well, what about getting the separate groups to use each other's expert system after you present them with a problem and you have to adhere to the advice of the expert system? In other words, you present them with a situation and you say, "I want you to use the expert system to guide you toward a solution". They use the expert system and they produce a product. What do you guys feel about this?

R1: It's kind of the same as presenting it?

I: It's kind of more experiential, they are experiencing it.

R6: My feeling about that is that it is just about as authentic as you can get it if you want to go the way of having an expert system developed to let somebody who doesn't know the expert system use the expert system because that's what expert systems are for, to get people who weren't involved in the development of the expert system.

I: So you like the idea?

R6: I actually like the idea, its more authentic than using you own expert system because you can read stuff into your own expert system but somebody else doesn't know the assumptions that you built into your expert system so that way round they use the expert system and they use the display stuff to come up with the product. That's what I always say, if you use the display section to come up with the product and you I look at what's in that product and what's not in that product it should give you a clear understanding of what went into the thought process.

I: Would it be a good idea to get the group to critique the expert system?

R6: I like something that R1 said earlier; you get the group to critique the expert system and then they get the opportunity to go back and fix whatever didn't work well. But this takes time. That is my big concern with what we are doing here is that it all takes time.

Transcript of focus group interview held on 25 February 2011

I: Your impressions of the way the ill structured problem was presented and constructed?

R2: I think that it was good. In the beginning it was difficult for me to comprehend, not comprehend but as you said, we always have the problem in mind and then you actually know what the solutions should be and the students should arrive at. So that's why we asked you for your papers so that we can see again what the problem was and then from t hen on we decided, OK, this is the problem and those are the things that we have to look at when we … the context, the message and the audience, if we want to do the flow-diagram, the design and arrive at an answer in the end. So, yes, its long, but I think that it has all the background and the information and it's not obvious what they should do. They will have to think and that's why R3 and I sat for a while and decided what it is that we will have to do.

I: So you think it is an improvement on the scenario Idea, a straightforward scenario?

R2: Yes, because it is not straightforward. You have to go through that and decide …you have to in the group decide what the actual problem here is. You have to see what the problem is before you can carry on and develop this.

I: And those dilemmas are good?

R2: Yes.

R3: OK, I think that the way that you presented it, if I can use R6's word, a brief is much more, umm, open in terms of not limiting the students to a specific scenario and its much less prescriptive and the fact that it is on paper so that you can go back to and refer to it again. Because as we went along we wanted to go back and consult it again because you build on your own understanding of its levels.

R6: Umm, I think we are probably moving in the right direction by having a very broad, almost undefined introduction. And then scaffolding your way toward a more defined problem setting, more defined definition of what the outcome is. I think that's a good way of doing it. Just a general comment, if hand out the homework assignment ahead of class that means you are directing what happens during class because they know that they will have to find answers to these questions. What will happen then is that they will use the interactions to answer those questions which are not the constructivist way. If you hand out the instructions at the end of the class, they don't have the resource of group discussion ahead of them to get the answers, so what they will have to do, they will have to consult their mental model of what occurred during the course of the event to answer the question so probably that is the more constructivist way of doing it. Just for the record, if you want to give them and assignment ahead of time to write a letter and one at the end of your interaction here, to write the same letter so that you can have a pre- and post assessment to see … it might make the learning overt to the learners. They might see the value of having done it this way.

R5: The open problem that you gave them fits nicely into your constructivist approach. Because it's open-ended and it's ill defined so I think it's a very well constructed open-ended problem that fits nicely into your premise of constructivism.

I: And how did you guys experience starting the development of the expert system?

R3: With everything that we have gone through and with all the scaffolding that we have had up to now it was actually not a daunting task, we had everything; now we just had to consolidate and put it all together. R2 and I enjoyed working on a flowchart. Just sorting out the questions first and then just to get a mental picture on paper and with all the layers what that mean. The flowchart proved to us that if we express it this way that it would be a logical next step. It actually led us in the direction of getting to something that would be able to answer different questions regarding different things.

R6: I think, umm, the fact that we did what we did last week was tremendously helpful in terms of what we did this week, in terms of having sat in front of the computer and actually design stuff. What happened was that that was just in time; it was just at the right moment that you did that. The learning was easy then because you weren't trying to learn software using some abstract scenario to build something. You were learning functionally, you know that this is what you need to do and you are going to use software and now we are using the software to try and achieve something specifically. So it makes the learning easier because you have got in mind what you want to get out of the system and now you are learning how to do that quickly, it was just the right moment. That made today's exercise much easier because now I could actually sit down and use your software to do my mental representation.

I: How is this influencing your conceptual understanding of what we are up to? I know that you are not necessarily novices but by plotting these things and developing these things you are changing the way that you are seeing it. Are you seeing that are you experiencing that yet?

R6: I'm seeing that a bit already. The comment that I made in the group now now, you need to ask a question, have selections and that's got to influence what's going to get printed at the bottom, tells you how scenarios and stuff like that are ultimately going to affect your product. And I think that's exactly the sort of understanding that you are trying to get, that different things will influence your final product. So I'm already getting a sense that as you go along you are going to get a greater sense of that but I'm already starting to get that kind of sense.

R3: I just want to add to that that I think the fact that the facilitators should be available to provide scaffolding is extremely important. The students shouldn't start working and then be left floundering.

I: What sort of scaffolding was useful to you?

R3: The fact that you were on hand, we could ask you something, it didn't slow down the whole process, we could ask you quick questions, we move on. It's not something we have got to ponder and sit and try and work out.

R6: You need to establish that the students must ask questions when they want to ask questions. Because what the question does is it gives you an indication of their understanding, and you can't really scaffold appropriately unless you know what they know, and the way in which you know what they know is they ask a question and as soon as they ask you a question you know what they are thinking and then you can scaffold appropriately. So that is very important that they will have the freedom to get up in class and ask you the question.

R3: Can I just add one thing so that the thought does not get lost. If you can have a big representation of the flowchart symbols, so that everyone does not have to go back to a handout every time it will speed up the process, I think.

I: Anything else? OK. Thanks very much.

Transcript of focus group interview held on 2 March 2011

I: Thanks very much everyone. Can I just get your general impressions of what we been have up to today?

R3: OK, what we did today I found very useful because the previous times R2 and I did a flowchart and the actual, I don't know what to call it, the coding, it showed us the faulty logic in certain instances. It helped us to develop in the IF THEN of an expert system, so we had to go back to the underlying rules and make sure that those were in place. So that made it very practical for me and that I found good. The discussion, the five minute discussion that you had with us in the beginning to show what we are going to do, the outline with the students I think that works well. My only concern is time but I know that it is difficult to predict ahead of the event what the time issue would be.

I: Just before you go, what did you struggle with today?

R3: I struggled with the fact that we did the coding …you taught us the coding that we will have to use about two or three weeks prior to today and suddenly I had to make that shift again and it was there vaguely but I struggled just to get that in place and that took time, to understand how to do the coding again using the program.

I: So if you had to do this immediately after you had practised this the first time around. Do you think that problem would have still been there?

R3: I think that it would have been much less of a problem.

I: Thank you.

R2: I made notes the last time that you showed us to do the IF and the THEN and the questions etc., and now my notes two weeks along the line do not always make sense to me as it did at that stage. So I agree with R3 if following period if I had used that and done that then I would have remembered and also if I do it myself then I would have seen OK this is how it works or this is a problem, called you, you showed me. I was out for a little while when I came back I was lost. I didn't know where to go for IF THEN, you know where to go for IF THEN. When he told me how the logic works I understood that and then you have to go back there and you have to do it yourself so what she did but if I don't do it myself and look at my notes and then go back and see OK, this is actually what happens then I am going to struggle, and that is why I struggled. Struggled with why do I have to hide, but I understood that in the end. Because it becomes an IF

THEN, if this then otherwise if you see that then it doesn't work. So I get that. My problem just now is that I don't know where to put in the IF statement, I understand that I have to do that and then it's going to show there. And another thing, if it doesn't work I don't know where to go back and look for the problem to correct the problem. If you talk about it makes sense and on paper … But then I don't know where to find that. I can't remember.

I: Besides the immediacy thing, besides the time thing, what would help you?

R2: Umm ja, I have to do it myself. I saw what R3 did for me because I'm not used to this and I'm right brained totally, for me what would help is if we did it immediately afterwards and I had notes and facilitator on hand and I could do it, try it myself, and if I make a mistake I ask you and then rectify. That's the short term memory, medium term memory, then I will remember. And then the next period I will have to do it again otherwise if time lapses, gone out of my head.

R5: I think that doing it for yourself is the best way because if you make mistakes you learn from your mistakes because you have to do it over and over because you have to get it right. Even if you … because we made a mistake with our coding and we also had to re-visit our logic but not only the logic of the programming language but also the logic of our CMAPP structure to see whether our option did make sense. So I think it's absolutely higher-order thinking because if you are solving problems the whole time, regarding your logic in the programming side but also the logic in the CMAPP, the communication theory side.

R4: And what I would also recommend to the students is that there's not only one person doing the typing because when I was following what R5 was doing sometimes you lose his line of thought but as soon as I started doing the second one on my own then it really settled in my mind.

I: I think that that is naturally how it is going to take place in the class. How are we going to overcome that?

R4: But usually there will be one strong person in the group that will do everything; we must try to avoid that.

I: How do we avoid that?

R4: Every second action a different person must do or something like that. But it's something to think about.

R6: Umm, two comments. I think importantly, the thing that I saw about R2 when she came back is that as soon as you lose track of what is happening on the screen you disengage. You could physically see that. And that's a problem … let's say for example that she is driving and she becomes quite good and R2 is not following yet, now R3 is going to fast for her to follow; then you are going to get that so we need to think of a way in which you can go through a progression where perhaps R3 does one or two but eventually the focus needs to go where everybody does stuff for themselves or they take turns. But I don't know whether the exercise is bigger enough for everybody to take turns and have enough exercise to actually build up. So maybe they will have to go and build their own one individually in some or other way. The other thing that I noticed now about the discussion is that everybody is talking about the software; nobody is talking about a conceptual understanding of the model. So that is not happening at this stage; higher order thinking about what the model looks like, is not happening.

I: I think it is.

R6: You know what, at this stage not yet; it will at that stage where you guys are probably. Because what happens is, you are starting to see Ok if I select this and I select this and I select this then I get this answer. Now you guys are starting getting there. Remember last week I made the comment, I was kind of unclear about this expert system thing until I started seeing that if I select this and I select that and I select that, what the response is at the bottom and then what I got here … remember what we did was to say the setting is informal and the subordinate and then our display was that the setting was formal and the subordinate, which is not an expert system it's just an aggregation of what your selections were at the top so we then understood that the question needs to be different and that the program needs to have some kind of intelligence that interprets your response and gives you an expert answer. So that I started understanding last week when I started working on the display line. So it's going to come. At that stage when you are working on the display line and you start reflecting about what an intelligent system is and how you have got to ask the question to get to the response … to get the appropriate feedback kind of thing. I think at that stage your higher order thinking is going to be quite a lot at this stage I'm not too sure. The reason why I made the comment that the higher order thinking about the model is not taking place here is because nobody mentioned it; I actually listened for that. Everybody is talking about the program issues here so maybe higher-order thinking about the program but not about the model.

I: What I noticed where I saw that higher order thinking was definitely taking place was that this particular group realised that the one question was not applicable if the other option was selected and that to me is a huge understanding of what we are doing and then they came to me and asked how do we get this to happen, it won't make sense if that question is there, and that is directly related to the domain that we are exploring.

R6: So there is a little bit of that; then obviously but a lot of what happened is how … how do we make that work in the visual interface. But like I say. I think once you get to the display side of this exercise and you start really seeing what your choices above do to your feedback at the bottom, that's when you really start getting the interrelationships between the questions that you are asking and the final influence they have on your message.

Transcript of focus group interview held on 4 March 2011

I: General insight comments suggestions that you would like to share with us?

R2: Umm, yesterday because I didn't do the work myself last time, I played around just with the questions and I could do that so that was a sense, I can do this, accomplishment even though that was basic. But I didn't have my notes so I didn't know what the coding was to put in the IF… I got to the IF and then I got stuck. I couldn't remember what you said but there was something in my subconscious I remembered. If I don't know what I do is right click and I look at all the options and I think maybe this one maybe that one. So I got to the IF statement but I didn't know the coding so I couldn't go any further so I did that this morning; then I got stuck, then you made it apparent to me that there must be an answer, that text value that I didn't put in. so I went off and I did the coding IF this and this and this and this and then that must be the answer, so I did all of this and then nothing happened. So when I spoke to R3 she said that not the questions but the answers don't work or might not be apparent to the user that … things that we assume that everybody should know are not so. So the reason why I think that people need an expert system is to tell them, be very basic, if you do this then go on to this or this means … if you choose a suit then it is formal. So obviously people will learn something else. Not just the programming of that.

I: How is this influencing the depth of understanding that you are achieving?

R2: Umm, it did because I'm not a logical person but if you struggle a little bit then you understand if you do this then this will happen; if it doesn't happen then it means something is wrong; then you have to go back and find out why and think but why didn't it work what went wrong, so I think that there is learning in that.

I: But that seems to be confined to the logic of programming itself.

R2: Not it's not; it's your own logic as well, the logic of the concept.

I: Is it improving?

R2: Yes, I well I hope so; I think that everything you did before they started working on the programming also made sense. R6 said that we worked on the flowchart beforehand because that made sense to us. But when we started working on the programming we saw that there were some flaws in the flowchart that we did in the beginning. For me still this works better to initially just pinpoint the questions for myself and then what I think should work and then when we do it and see that it doesn't work then we can go back and say OK why didn't that work? Was there something wrong with our questions here or the IF THEN statements?

I: Just one last question for you R2; what was missing in the flowchart?

R2: Maybe it was the questions, there wasn't a specific IF THEN statement to get to an event in the end; I think that was maybe the problem.

I: OK, thanks.

R3: I would like to elaborate on what R2 said because we initially worked together. What I found was that I got stuck at a certain question and then I realised that I am actually almost giving them multiple choice. Choose one and then the next but real-life does not work like that. So you would have to input into the program so that the inference engine can give advice you would have to input more underlying information and then we make assumptions about concepts we assume that the model the CMAPP, we assumed that the students … we worked on our knowledge not what the students would have and R6 made me aware of that. Because if we say formal informal it's not necessary that they would know what formal informal is. So in that way you asked R2 questions about the system and the concepts, so in that way I looked at the concepts of the model again and realised that you can't make assumptions that people would know things. You have got to go back to the real-life situation and think, what would they see there and you would have to make provision for that. And also if I worked through the whole thing it would be IF THEN IF THEN but I could only work on the one leg of formal and that would disregard any other choice that the students would have made and we would have had to do a whole different level which I'm not sure we would have approached that.

I: Now tell me something; how has that modified your understanding of a formal context?

R3: It has, because I would say formal is, formal is if the people wear suits in an office that would be the off the tip of your answer that you would give. But formal can take different shapes and a student could … or someone approaching the expert system could come with a specific idea what they have seen, so the expert system will be able to give advice based on that because there are so many variables and factors that come into that.

I: So by trying to articulate that within an expert system environment has modified your understanding of formal really is?

R3: I would say more to the extent of how the students would experience that but yes, to a certain extent yes, because it's not just an answer that you can give someone. And also if you get to the end, umm, R6 told us that R5 and them they worked basically you put in your IF THEN statements from the bottom so that you don't have to choose this choose this and then that and then I thought, *So what is the answer now.?* So the logic developed and my ideas of the concepts developed also. And I also got an aha! moment about OK, this is what an Inference engine should be doing.

R6: Umm, I think what happened to me in terms of learning about the model itself and the components of the model once we had the aha! moment of what an inference engine really is then it forces you to start looking back at what it is that you are looking for to decide, for example, that the tone is formal or the tone is informal. Umm, and once … what happens then it forces you to pay attention to what the fuzzy indicators of formal or informal. And again I think at this level when you start coding that kind of stuff, that's perhaps the learning that's going to take place. It's about what things to look for if you look at formal and informal, what kind of things in real-life, if you are in a setting what kind of things are you looking for to decide whether that's informal or formal. Because that influences the questions that you are going to ask. So I think that at this level of coding that's where the learning is going to take place. I predict that the interdependencies between the different components in getting to your final product, I think that is going to become apparent right at the end when you start working on your display line. I think that's where that's going to start setting in. This is to me a hugely enjoyable experience. I'm going to go back and use this and play with this stuff. I worry that we might not know a lot about programming per say, but what we do have is an advantage over the typical student; we have fairly advanced cognitive skills. It makes us deal differently with these kinds of challenges. We have the ability to process differently. I am a little worried that the students will not even progress at the rate that we have progressed at. I think that you are going to have to pay a lot of attention to scaffolding in the class and I think that you are going to have to scaffold far more than would be necessary in a group like ours where the cognitive skills level is higher than you would typically find in a group of students.

I: Tell me something, the fact that we all have a reasonably good understanding of the concepts that we are exploring, is that not making the learning as apparent as it might be to the student?

R6: You told us right at the beginning to take the textbook and go and read this chapter. And that's where I happened on the idea that perhaps our cognitive skills are perhaps a little more advanced. Because that to me was enough to understand the concept, so I walk in here and I already have an understanding of the concept so the whole exercise in that sense was a little artificial because I know where we are going towards. Whereas if you are working with students who have got no idea at all, the learning might very well be different to what occurred in this environment.

R5: I think what's brilliant about the expert system is that students have to reflect on their learning, so it's not just … yes, they create a database of information but if they get this right they will turn this information into knowledge that they can apply. So I think that this makes this like constructivism, higher-order learning. It's not just learning a collection of information they have to infer knowledge to arrive at a decision. So I think that the reflection process is very …

R3: Can I just add one thing? What this did for me is to change the way that I would teach something like this if I had to teach it again because it forced me to look at it the way that a novice in the area would approach this. So that was also an eye opener to me.

I: So it changes the way that facilitators understand what it is that they should be communicating?

R3: Ja.

R6: I think what would have happened for me if I had to teach this subject is that once I read it I had an understanding of the model but it was tacit understanding. But because we have worked on this development it kind of pointed out very discreet things that you look at. Discreet observations that you have to bear in mind to get to your understanding which at first was tacit but now I can actually tell you a range of things that explicate this tacit understanding. And now when you need to teach that … because you have got a tangible list of things that you were previously intuiting you have now got a list of things that people can actually look at. That's what it did for me it kind of concretised the small little things that you need to look at to get to this previously I would have had an intuitive understanding of whether it was informal or not and now I can actually tell you, if you look at this and this and this you can decide that its formal.

R3: What it did for me also, it was …. We used to teach here, because of time limits, because of English language proficiency, because of all of those reasons, we used to teach and listen, this is the answer and this is it. What this made me think about was different personal understandings of concepts and that you have got to make provision for that. So you have to allow the student to develop his or her own understanding. And you have got to make provision for that and that is why I think the expert system that we had to develop could become so massive because you have got to make provision for that and where do you draw the line? Because my understanding isn't the students' understanding, isn't the next student's understanding and if you really want constructivist learning to take place you have got to keep that in mind.

I: Anything else? Thanks very much.

Addendum G

Transcripts of focus group interviews held with the student sample

Transcription of focus group A

(No editing of responses)

Researcher: What do you guys feel about using computer technology to learn in this way?

FG 1.1.1: It makes life more easier because computers have become more influence to our lives at this period of time.

Researcher: And learning Communications using computers by creating an expert system, how are you finding this? Challenging, interesting annoying, disruptive?

FG 1.2.2: I think that it is very interactive. Kind of a way exposes you to the outside world because I think that expert systems are being used outside for different purposes and then this gives us a broad of how communication can be used and expert systems cause I didn't know expert systems before today and knew what it was … I had probably used them but I didn't know what I was doing but now ...

Researcher: Anyone else? Yes, Sir?

FG 1.3.3: I found it interesting because some of us we learn easy doing things practically.

Researcher: Anyone else?

FG 1.4.4: I found it interesting. You know … let's take … if it was information technology; the world will be the same. The expert system is very good, for instance, the introduction, you told us like if there was like old men who's having minds about something for like if you want to go to job interviews and all this stuff. So it is good the expert system, its helping for … its working like humans mind, ja, I think it's helping.

Researcher: Anyone else? How is this affecting how you understand the subject? Remember we are here to learn about communication; how is it influencing how deeply or how well you understand what communication is about?

FG 1.4.5: It improves our communications. Like we learn what our managers out there in the business world expect from us.

FG 1.5.6: It does improve communication in lots of ways but at the end of the day there is a disadvantage to it. For example, we are the only ones actually … if you are doing IT; we are the only ones who know what expert systems are. If you have to introduce this subject to other courses like management or HR or whatever then I think it will be influential because we are not the only one who are doing communication we are not the only one who are communicating, we are communicating with other people out there. So it would be better if this was introduced to all the courses that are in this campus.

Researcher: What I'm really trying to ascertain is how is the process of developing an expert system influencing how well you understand communication. Because basically what we have been up to over the last couple of weeks is, we have been developing an expert system. How is the process of developing that expert system influencing your understanding of communication?

FG 1.3.7: It's working, that's what I want to say, it's working. Why am I saying it's working, why? All those videos that you showed us, like I could have just looked at them and thought , you know, I don't care, but after I've seen them then I could see, OK there was a problem there what was the problem. Like we were using CMAPP, I didn't know what CMAPP was but now out there, when I'm outside … the other day I was walking and seeing two people talking and I was able to apply CMAPP to that … I was watching TV and I was able to apply CMAPP to context … especially context because we didn't do message and all those others. It's very influential.

FG 1.6.8: And again the expert system it gives you ah… it broadens your mind. Like you won't think as an individual but you will think for the other person, you will think out of the box, you see.

FG 1.7.9: Just adding to what she was saying; now it's working like she was saying. Now when I'm watching a movie or something, before I'm watching the movie and OKOK its funny they're laughing like doing stuff, but now I pay attention try to take like something from what they are saying and know what they are talking about. When we have to do something now we don't just do because like it benefits me. I have to think, if its fine for me it will be OK or understandable for others. Like other people. I think that's the way the expert system is

FG 1.8.10: OK, like what I saw from the previous thing, I mean ah views, learned that ah, like there in ah industry, it's not just all about the employer it's also about the employees and the people around you, they contribute a lot to your communication and your listening skills.

Researcher: And has actually developing the expert system given you that insight or is it just your exposure to CMAPP that has given you that insight?

FG 1.3.11: Exposure to CMAPP.

Researcher: And how has developing the expert system influenced your understanding of CMAPP? Cause now you have to think about the expertise that the expert system is designed to mimic. Are we still too early in the process or are you seeing something happening inside your minds?

FG 1.3.12: It's still introduction it's still very difficult, because for some of us it is still even difficult to apply CMAPP, its difficult, the programming, everything is still difficult, we are still learning, we still having problems with the IF statements. So it's still introduction, getting there.

FG1.8.13: Yes, like we are still in the process, I think more time will be … We will get it.

Researcher: How is struggling the way you are struggling influencing the way you are learning because sometimes when we struggle we learn?

FG 1.8.14: Ja. I was struggling to have great outputs because by the time we are struggling is … we keep on asking others and then we have better outputs and then the great answers and stuff.

Researcher: So the struggling is making the learning more …?

FG 1.8.15: More better, ja more better.

FG 1.3.16: Because the more you struggle the more you ask questions.

FG 1.7.17: And the better you approach questions you know, the better understanding you have for ja …

FG 1.5.18: It's great because the output of the debate is the correct answer so if you debate and then you are going to have the correct answers and then you are going to do the great thing.

Researcher: How easy is it to learn using the software? Is the software easy to use?

FG 1.3.19: It's easy to use 'cause we have done programming before. Before you start ... we have all done Visual Basic so, umm, IF statements it's easy to use that output like you already understand that language. But if you are not doing IT it's going to be very very difficult. But because you have done programming before, and some of us are still doing programming, it's very easy. You actually see that in programming … it's the same thing except it's a different syntax, it's the syntax that we use that's different.

FG 1.7.20: Ja, we are applying the same knowledge like it's the same as Java, everything that we do there its Java stuff. If we do Visual Basic, which is the basic of IT, we are going to do this stuff.

Researcher: And tell me something you guys, are you enjoying this?

Group: Ja, Ja.

Researcher: All of you are enjoying this?

Group: Ja.

Researcher: Would you like to learn all your subjects like this?

Group: Ja.

FG 1.3.21: No, It's a little difficult … it's difficult. But I think learning using different things. If in all my subjects I was using one thing … you are not exposing yourself to other things. So it's good when you are doing programming using this software, theory you learn how to read because If I didn't know how to read I wouldn't know how to apply you knowledge in this. So you need your programming yes, and you need your basics, you need your theory.

Researcher: So you would like a bit of variety; you don't want the same style used for everything?

FG 1.3.22: Yes.

Researcher: OK, but you guys are enjoying this. What's not working here?

FG 1.7.23: At first when you started talking about the expert system, I didn't understand ... like ... because I thought we were doing a basic program, because we do programming like where you put in certain inputs and then you get a specific answer. But now after you explaining ... like after a few classes I started getting the fact that this system actually, umm, accommodates like a whole lot of situations. It's like you give it a problem and then it gives you a solution and then the problem, doesn't have to meet like all the conditions but then it gives you like advise, you don't have to solely take it but, you understand.

Researcher: But yes, what's not working? In this whole learning experience, what's not working for you? What do you find irritating or do you think can be done better? What would you say?

FG 1.7.24: I think more practice on the expert system would actually be … if we were more comfortable with the coding and the …

Researcher: Anyone else?

FG 1.3.25: The coding, you know when it comes to the IF statements; I don't think that it's working because everything there it's cluttered, like it's really cluttered. Like in VB it comes in steps, you know, this is the first step this is the second so everything there it's just one line, like if you had to read that, if you had to give somebody who hasn't done programming like they wouldn't be able to read that. So I think the method there when you use your coding if it was ... step by step it would be easier.

Researcher: So you say that using the software is a little challenging because you can't see the logic of your argument in one view?

FG 1.3.26: The user interface; its fine and the coding.

Researcher: And the way that we are doing this, giving you an understanding of what an expert system is, giving you an understanding of the expertise, does that make sense to you guys?

All: Yes, it's making sense.

Researcher: OK, does anyone else have anything to say, just generally, just anything?

FG 1.7.27: I want to ask, if ah, if there are possibilities to change the software. Because we are the student, we are doing the English, but some of them they are not doing programming so it's very difficult for them to be on the same level as we are. OK for me, when it comes to the IF statement I can see, because using the operators I can use them but to those that are not doing Java or other languages is difficult. At least the software ... if they can change it.

Researcher: Do you think that the more the people use it the more comfortable they will be with it?

FG 1.7.28: Ja, I think so.

Researcher: So maybe that's just what you are feeling now, maybe if I ask you in another two weeks' time you will feel different?

FG 1.7.29: I don't know.

FG1.3.: I wouldn't feel different because like I said anybody who is doing Logistics, if they had to come … I think it will … for us it to OK just a few days to understand it, why? Because we have done programming before. Someone who has done logistics knows nothing about programming. All they know about computers is typing, that's the only thing they know, yes, they know a bit of PowerPoint, they know a bit of Microsoft but they know nothing about programming. This is programming.

Researcher: So what would the solution for a Logistics student be?

FG 1.3.30: The only solution would be to use the expert system. They are the end user.

Researcher: But I want to get them to create it, because creating it is where the learning happens; using it is not where learning happens. How would I get them to create it? You say the software would be too challenging for them; how would I make it easier for them?

FG 1.8.31: Sir, each and everything like the first time you learn is challenging, even for us, OK we have done the basic VB before. It was challenging but then we managed to pass it. Even for them, it's going to be the challenging at first. Each and everything at first is challenging, but the out puts it's there…

FG 1.3.32: Eventually, but it will be a slow process.

FG 1.8.33: Can I ask a question? What is your final plan? Is it to incorporate this type of learning in every subject? So your plan for us was to use the expert system to get us to get more of an understanding regarding communication?

Researcher: Is that happening?

FG 1.8.34: Well I can say that I realise that communication is a very very broad ….

Researcher: And actually thinking like an expert and designing an expert system made you realise that?

FG 1.8.35: Ja, that's what I can say.

Researcher: And is that helpful to you?

FG 1.8.36: Ja, it's helpful in way 'cause …

Researcher: It's given you a new understanding of what communication is about?

FG 1.3.37: If this is just for us only then, and communication is broad, then it's not really communication because I am not always only communicating with an IT technician, I'm not always communicating with these guys. When I go to the industry, when I finish this and I go to the industry I'll be working with somebody at management level or in HR because I'll be helping them 'cause everybody is using computers. I'll be the one who is solving their problems with computers, right? So I'll be communicating with those people, so if I come up with this and I say this is your solution, if you do one two three … it's going to be difficult for them. So I think this thing, this software should be introduced to everybody, whether Logistics or HR or whatever.

Researcher: It's not about the software; it's about your understanding. The software is only a tool that enables you to understand something at a different level. Is that happening?

FG 1.3.38: Oh, yes, that is happening.

FG 1.7.39: Yes, that is happening.

Group: Yes.

Researcher: So by creating this expert system you are understanding communication at a different level?

All: Yes, yes.

Researcher: So everyone kind of agrees to that?

FG 1.3.40: Definitely.

Group: Yes.

Researcher: Because that's the idea. The idea is not to actually develop a piece of software that can be used by marketing people. It is to improve your understanding of what communication is.

FG 1.3.41: Oh …

Researcher: And you are telling me that that is happening?

Group: Yes.

FG 1.3.42: Yes, that is happening.

FG 1.7.43: 'Cause like when you record the software, it seems like you will make like the user, the user's mind. The user is going to click and is going to mimic like I am the one who is going to mimic the user's mind. The mind like I don't know that person but I like it is improving like …

Researcher: Your insight?

FG 1.8.44: 'Cause communication is broad it is all about understanding and I think all of us we … I mean we found out the other things that we didn't know … Isn't it?

FG 1.3.45: Ja.

FG 1.7.46: If maybe inside some body's mind that would know that you are great, like your communication …

FG 1.3.47: Communication skills are good.

Researcher: All right guys. Have we finished? Is there something that someone wants to say?

Transcription of focus group B

(No editing of responses)

Researcher: For the past three weeks or so we have been talking about expert systems; we are now using a software application to develop an expert system. I would like to get some understanding of what you feel about what we are doing.

FG 2.2.1: It's complicated.

Researcher: Why do you say so?

FG 2.2.2: Because we are doing some ... Like the examples you gave us were easy, about the dog or whatever but now we have to create something that has to tell people what to do, which is hard.

FG 2.2.3: And communication is really broad; it's like a broad subject, so most of us don't really know where to start.

FG 2.3.4: The advantage about it is like, I think the person who benefits is the end user after all, it's complicated for us but after the final product it's beautiful. It's easier for the user to use like, with those dropdown buttons … it's exciting. Even though it's complicated and it's hard to create but the final product is exciting.

FG 2.4.5: I think I am going to design an expert system in the future.

Researcher: You are going to design your own expert system in the future?

FG 2.4.6: Yes.

Researcher: So you are excited about it? You find it interesting?

FG 2.4.7: Yes.

Group: Yes.

Researcher: Anyone else?

FG 2.5.9: I think it gives a clear understanding of what communication really is.

Researcher: OK. Why do you say that?

FG 2.5.10: Because like, there are many things we didn't know about communication but at the moment we know the steps and procedures to follow in order to have a successful communication.

Researcher: It is interesting that you guys say that it is complicated. But the fact that it is complicated does not necessarily mean that it is bad, it does not mean that learning is not taking place. I want to get an explanation from you. How does the fact that it is challenging affect how you understand what we are doing?

FG 2.2.11: The fact that we have little time, we don't have much time to come up with the solution to … is very complicated for us.

FG 2.6.12: We need more time to do it.

FG 2.7.13: If you take time to think what steps to take when creating a system like this you know, what steps that you have to take when you have to present something. Like, it makes you think of those things, you can't just present something; you know the barriers that might occur or something.

Researcher: The way I understand you now is that one of the challenges is that there is very little time to do this, but what I am really trying to get at is the fact that it is complicated allows you to see it in a different way; am I right?

Group: Yes.

Researcher: What is that different way?

FG 2.2.15: It becomes a problem because you need to know what the person is going to say if ... you must have options, you know that you understand what you must do and ... you should be clear you know … if she asks … if a person asks question you must give straightforward answers you must get the point.

FG 2.3.16: And you must probably think like somebody else, you can't think like you think.

FG 2.2: It forces you to think outside the box.

Researcher: How easy are you finding it to use the software?

FG 2.2.17: The software is very easy; it's like Maths, OK not Maths …

FG 2.3.18: Because we are used to programming anyway, we are IT students so we are very familiar with computers and software like that they come easy for us.

Researcher: OK, so you don't think that the software is much of an obstacle to the learning?

Group: No.

FG 2.3.19: It's too easy compared to other programming languages.

FG 2.8.20: It's too much, you have to take your time and study it.

FG 2.3.21: I think the only thing that take time is developing that flow-diagram. Creating the actual expert system doesn't take time; it can take you about 30 minutes' time. But then drawing up that flow-diagram … having to come up with the options and the topic, that's challenging for us.

Researcher: That takes the time? But the actual development of the expert system itself is not an obstacle?

FG 2.2.22: Plotting it down is the problem ... when you have to … think.

FG 2.3.23: Because basically that's … for us as students we feel like we are creating a user interface, we are not coding anything we are just creating a user interface. Those, what you call it, those value names … description … whereby we go to the next window. We are just naming, we are not coding anything in order for that thing to process, we are just coding.

Researcher: You actually are; you are actually putting the logic into that as well by putting the IF statements for the …

FG 2.3.24: Oh, OK maybe that's where the coding comes in.

Researcher: OK guys, are you enjoying learning this way?

Group: Yes.

FG 2.2.25: We are enjoying because we are having more experience.

FG 2.3.26: This thing about working in groups makes it more exciting. Because what I don't know my friend might know, so it makes it more exciting, ja.

FG 2.2.27: We gain expertise from each other.

FG 2.3.28: We know how to communicate better.

FG 2.2.29: But it is also quite challenging I must say, because if some person does not want to work and you want to work and then the other person does not want to think you have to think on your own.

Researcher: So working in groups is also challenging? It's beneficial on the one hand but it's also challenging on the other?

FG 2.2.30: Ja.

Researcher: Gentlemen, do you enjoy studying in this way?

FG 2.7.31: Yes, due to the fact that it is new to us. Each day, day by day we learn new things so that's why it's so nice for us, every day we learn new things on it.

Researcher: Now, I'm also interested to know how is learning this way, by creating an expert system, physically doing it on your own, different from if someone stood up in front of a classroom and just lectured to you? How do you understand things differently?

FG 2.2.32: I think in the end you will remember this, after all the battling and the crying, you will remember it better than if a lecturer just stands in front of you and actually tells you what to do.

Researcher: Why will you remember it better?

FG 2.3.33: Because you are doing it practically, you are doing it yourself, that's why you will remember it better.

FG 2.7.34: It is easier to remember something that you have done practically than something that you have just studied.

FG 2.3.35: And honestly speaking, some lecturers don't know how to lecture. There are a lot of barriers, you find that a person comes in the morning, you don't know if he is moody or that's the way person is.

So there is a lot of barriers between us and the lecturers. So a system won't come in the morning … it won't be moody.

Researcher: OK, does anyone have anything else to say?

FG 2.8.36: We are just willing to learn more, we want to learn more.

Researcher: My last question for you guys: learning that you are acquiring now, will you be able to apply it in practice?

FG 2.3.38: Absolutely.

General: Yes.

Researcher: Why?

FG 2.7.40: Well, I think that's the purpose of the expert system is to teach us, both the creators and the users to actually become better communicators, so I think that it will beneficial because it is user friendly and understandable.

Researcher: Anything else? OK, thanks very much.

Transcription of focus group C

(No editing of responses)

Focus group 2

Researcher: How do you find this experience? How do you find developing expert systems to mimic the reasoning of a human communications expert? How are you finding learning in an environment like this one?

FG 3.1.1: I think it's quite exciting because it is something new for us and we are learning new things each day. Yes, like in communication we are learning new things that we didn't know.

FG 3.2.2: It's very exiting the … this era we living, technology is always on our side so every time everything we learn we try to convey it in technology so that we can be busier, so it can be helpful to us. So I think it's better.

Researcher: Anyone else? What do you feel, Sir?

FG 3.3.3: Ja, it's interesting and it's great 'cause its help people who don't know the communication because for some of them the communication is poor; it helps them to improve their communication as it mimics their minds.

FG 3.4.4: It's very interesting and exciting 'cause I would say it's one of the things that breaks the communications barriers and gives people the broader mind in understanding what communication is and how to use it, how to apply it.

Researcher: Anyone else? OK, I heard words like *interesting* and *exciting*; what is interesting about it? What is exciting about it? Remember ,the idea here is for you guys to be learning. The creation of the expert system is simply a tool that enables you guys to understand communication better. What are you finding exciting and interesting about it?

FG 3.1.5: I find it interesting because it gives me a challenge as a person to think outside the box, not inside to be contaminated and don't think the right … I have to think … it makes me think broad and using different ways in the way that I communicate with people. Now I know where my errors are when I am communicating with someone and if someone is doing something wrong concerning the communication. That's how I find it interesting.

Researcher: So you say you think outside the box? Just expand on that a little bit. In what ways are you thinking outside the box?

FG 3.1.6: Before I never used to think of ... When I'm communicating with someone I just wanted to get the message across, I didn't look at the environment and the things that were around me that would affect the communication and things that I was doing like, for example, body language, how the person will actually receive the message that I'm saying to them and the tone of voice that I used before.

Researcher: And how has developing an expert system helped you to come to that realisation?

FG 3.1.7: It actually helped me a lot by using the CMAPP; I actually learnt a lot from it.

Researcher: And developing the expert system?

FG 3.1.8: It also helped because I learnt how to use communication in different situations better than in one situation where I have to communicate with friends or a family member or the lecturers.

FG 3.5.9: Just to expand on that, I would say that since we started with the project ... like ... learning experience for some of us. We never new anything about CMAPP before. Now we know that in communication there is something like it's called *context*, there is something that is called *message* that needs to be conveyed. There's barriers and things like that. It also help us like when we are building one of the projects, that help some of us to guide like ... what can I say. As I'm creating the expert system, I'm creating it from the language that I've learnt from the project, guiding someone who never had the chance to learn about this, by showing him or her that if ever you are using an expert system when you want to convey a message to a certain group, this is the way you should do it and if ever it is for less people, this is how you should do it. This is how is the kind of medium that you need to use.

Researcher: OK; now I hear you say that the CMAPP concept has been very helpful to you. How has your understanding of CMAPP been affected by the development of the expert system? How has it been changed?

FG 3.4.10: Like I said before, we never knew anything about the context, influence of the communication when you are communicating with somebody else. But now since that had come to the play … So that's how it is, yes.

FG 3.1.11: I think also using the CourseLab it was something new for us, we didn't even know there was such thing, such language, it was something new and it was exciting for us and it was interesting in a way to learn more about CourseLab because we didn't know anything about it.

Researcher: OK, and the same question that I asked this gentleman*, How has developing an expert system influenced your understanding of*

CMAPP? I hear that CMAPP has been a useful to you guys because you now understand that communication takes place within a context and so on, but how has being asked to develop an expert system affected how well or how differently you understand that concept?

FG 3.1.12: I think firstly you have to consider a lot of things before you communicate, such as the environment, the way you talk to people. That has helped us a lot because we didn't know that he environment or even some of the barriers can somehow interfere the communication. But knowing where you are … the appropriate place … we know the appropriate place to communicate … like in a meeting we can use a more open place or you can't just call people and say we have got a meeting right now. We have to consider certain places.

Researcher: But how has developing an expert system improved your understanding?

FG 3.1.13: I think in terms of … improve my understanding in communication, it has because right now I can say that we can talk openly with confidence to other people and it has improved my knowledge and understanding of communication.

Researcher: How? Guys, the same question generally, the actual process of developing an expert system, has it influenced your understanding of what we are up to?

FG 3.5.14: Yes, I think I'll be repetitive but let me just say it. Like other my other class mate says …

FG 3.4.15: OK like, it has made things easier for us as a learning tool. Being able to come up with points, I mean like questions which are based on the, umm, based on the communication barriers and stuff, so they have broadened our understanding towards the communication, that communication is only, is not only a one-way tool, it is a two-way tool; it's all about understanding and listening and ... ja.

Researcher: OK, so coming up with the questions has helped you see communication differently? And besides coming up with the questions, the actual development, what has that done for you? Anyone?

FG 3.6.17: It acts as a guideline for communication, as like the questions that you ask … how can I put it …

Researcher: Anyone else?

FG 3.4.18: What was the question?

Researcher: The idea behind developing the expert system is that you guys can think. What do I want to ask? What am I getting at? What is my advice? OK. That is what an expert does. That is what an expert system is designed to do. Are you guys doing that? And how has the process of doing that changed the way you see communication, changed the way you understand communication? OK let's think about that. What do you guys find challenging about this process? Developing an expert system, using technology in this way; what is hard for you guys?

FG 3.5.19: The audience sir, when it comes to audience, like in a meeting OK I know in a meeting there are audience, but what if I am sending SMS or fax, is it also part of audience because CMAPP includes audience only.

Researcher: OK my question was, umm, using technology has certain challenges. What are you guys finding difficult about using technology in this way? Is the development environment easy to use? Is CourseLab easy to use? Working in groups, how is that working for you guys?

FG 3.4.20: Working in groups is like sir, like the cooperation, that has been a problem, sir.

Researcher: In what way?

FG 3.4.21: Like you will find that some people are not contributing towards the programming, they are not coming up with any ideas towards the CourseLab thing.

Researcher: And how does that influence your progress in the environment?

FG 3.4.22: Well as an individual I learnt some of the things but I don't know what about the other people who are dependent on others. Are they gaining anything or ...

Researcher: But how is the fact that they are not contributing affecting you?

FG 3.4.23: OK, as an individual I feel that, umm, I've been used in some ways, you know, yes.

Researcher: So you feel that it is unfair?

FG 3.4.24: It's unfair, but at the same time it encourages me to do more because I get to learn other things.

Researcher: OK. Other challenges that people have experienced?

FG 3.5.25: I don't have any, no challenges.

Researcher: And you, madam?

FG 3.2.26: I think using the CourseLab, because, umm it's very difficult because you have to think if your communication model will really help the next person who is going to use it. So it is challenging because about different things, how it will help them or be useful to them and how the end result will be for them. Be useful or not useful. That's more challenging and like he said the groups, you can find sometimes that you don't agree about the same things. We see things differently, so that's more challenging.

Researcher: OK. When you don't agree, how do you proceed from there onwards?

FG 3.2.27: We vote, if maybe it's two against one then we say no we are going to use this, if it's one against two then probably we will not use this at all.

Researcher: And is disagreement good when it comes to learning?

FG 3.2.28: It's not good because it takes us back. We end up arguing and not getting the job done at the end of the day.

FG 3.5.29: I think it's good for me because if you have disagreement it makes you think more to get like better idea or better …how can I say resolution. Because let's say I say something and all my group say "yes" and someone say also "yes", if it's good it's good for all of us. If that idea is like not that really good and someone come up you know, I think this is not really correct, is not good, is better like … to … I think this is not really good but I don't have an idea that is better than this one, all of you will be like, OK, let's all of us think OK, what is suitable for this situation or for this problem. I think disagreement is good, in like a good way of course from there you would be able to think more and more. When you disagree and you think more I think it's better than … for your understanding and your knowledge also.

FG 3.6.30: Disagreements are sometimes really good but sometimes really bad like 'cause we are working with different types of people. There are those people, if ever we are disagreeing … whatever we are talking … we won't come forth 'cause it's like whatever what I am saying the group doesn't want to accept on that. But like on that … it also helps the group to modify to say OK, you came up with something like this but if we are using the very same method that you are using but we modify it to say do like this and maybe as a group we will come together and say but maybe the one that you have just suggested is better than when you started. Like that you ...

Researcher: So it can be good but it can also be bad?

FG 3.6.31: Exactly.

Researcher: What do you guys think?

FG 3.7.32: Yes, it's good sir, 'cause by the time we disagree you are going to get the powerful solution and then if ...There are some of them who disagree even if you try to convince them, then you consult and then you will get the solution that will cover all of us.

FG 3.8.33: I think that its good because in a group, when you are working together, obviously there is going to come a time where all of you don't have the exact same answers, you don't agree on the same thing, so you have to think more and then you have to come up with different ideas and then, as he said, we have to consult so that you get a good answer.

Researcher: Anyone else got something to say there? All right guys, are you enjoying learning like this? Is this an enjoyable experience for you?

FG 3.4.34: Yes, working in groups and working as an individual to come up with some of the things like it really gives one a challenge but also gives you, like let's try to say OK; I had a challenge, I did this, I've proved this, I've done…, I've worked with the group, we have all agreed on the same thing; then as a person you really learn from that.

Researcher: OK. You guys say that it is enjoyable, why? Why are you finding this enjoyable?

FG 3.3.35: It is enjoyable because, like he said, we learnt, let's say in a group, we are developing something or we are discussing about something. From there I come up with ideas, like what I know or what I think that is right and someone else come up with another idea. From there I will be learning more and my mind, what can I say, going to be more open. Ja, that's what I think is the enjoyable thing, we got … We learnt something new, something more that we didn't know before we challenge ourselves … I think that I'm not like able or capable to do this but finally I did or I contribute something on what we are doing.

FG 3.5.36: I think it is enjoyable because from a group we combine all our knowledge and compare which one is better and … when we find which one is better we used and that one will help us in the group, yes.

FG 3.6.37: Yes, it is good because by the time you can see but no, this expert system that you are going to use, even the people that are going to use, they are also going to argue. So by the time we are going to argue we are going to get the suitable answer that will cover the people that are going to use the expert system.

FG 3.1.38: I think that it is also helpful because we think like experts now and it is preparing us for our future in workplaces.

Researcher: One last question: what can we do to make it better, what improvements can you think of?

FG 3.4.39: The programming language, sir.

Researcher: The programming language?

FG 3.4.40: Yes.

Researcher: What is wrong with the programming language?

FG 3.4.41: You know, umm, there could be some, I mean like those things that could like assist the person who is programming the language because there is nothing there; you are not able to know if you are on the right track. Ja, showing the errors.

FG 3.5.42: To add on to what the guy has just said. I would like to agree on that. Like I would say, CourseLab is a good project to work on as a student, not only in IT but maybe also in other faculties this could be applied. So using a different syntax, like a more user-friendly syntax, ja would also be a great thing to do, would be an improvement.

Researcher: Why do you say that?

FG 3.5.43: ‘Cause OK, if I am in IT and I am doing this, like I know most of the stuff like Java syntax and so on. But for someone who have never done this before it will also give that person a challenge working with something like this.

FG 3.6.44: I find out that its good, the programming is good, that language, but as I learn in French ... that means repeating something is there … it will help you to understand better. I think those exercise we are doing, we are not doing too much exercises. We do maybe two, maybe a week, we will improve.

FG 3.7.45: Just to add on to what he is saying, I think he means we have to, how can I say, we have to have more lessons about expert systems because using CourseLab, its good; let’s say for us IT students because we know a bit about programming and like if we learnt more … we have more things about expert systems I think it will be better for us, ja.

Researcher: All right; does anyone have anything else to say? Yes, Sir?

FG 3.5.46: I think that it should be introduced to other departments so that those people should have that chance to communicate with other people using that expert system.

Researcher: Anything else from anyone? OK. Thanks very much, guys.

Transcription of focus group D

(No editing of responses)

Researcher: How are you finding learning in this way?

FG 4.1.1: At first we thought that it would be just something simple, we get into a lab, we do everything, we get done within one hour but as time goes on we find it more difficult because it needs more time where a group has to sit down analyse everything just to get the work done properly. It just needs more time to do it.

Researcher: OK, thank you. Anyone else?

FG 4.2.2: It needs more logical thinking because when you are doing the program sometimes it becomes more confusing. It become more confusing, ja.

FG 4.3.3: I think it helps you think outside the box 'cause you have to think beyond your school days. You have to take your communication level into the workplace and all that. So it helps you think beyond what you like you know your level at school level. 'Cause now, if I have a presentation I'll just do it in class in front people but now I have to advise people on how to make presentations in front of shareholders and that, so it takes me to a certain level and I'm thinking outside my box and I'm getting outside my comfort zone.

FG 4.4.4: Ja, I think in terms of adaptability, people who use it will be able to adapt it faster. As for us, creating it is more challenging. And the thing with the time, I think the timing is all wrong. If maybe we had started in February or something, Ja.

Researcher: OK, why do you say that?

FG 4.4.5: It added a lot of work onto our workload that we already had.

FG 4.5.6: It is difficult because when you drafting it on a page it is more easier but when it comes to doing it practically; it's very difficult because you have to have time and implement all the ideas that you have.

Researcher: Anyone else? Sir?

FG 4.6.7: Actually it's not difficult, it needs our time to sit down and discuss and plan before what's going to do first because it's not that difficult. Ja, but we need to sit down and plan it first.

FG 4.7.8: I think as the person who is designing, it's difficult for the person who is designing it but for the person who is going to use it its easier and enjoyable for the person who is going to … for the user, but for the designer, it gives a headache. I think so.

Researcher: OK. What most of you have said is that it is difficult and I know that it is difficult, it's meant to be difficult but the fact that it is difficult does not mean that it is bad and it does not mean that learning is not taking place. Give me your insights into that; what sort of learning is taking place because it is difficult?

FG 4.1.9: As we thought, we thought it was going to be just generally, we give advice generally in life but we've got to think it's about communication where learn more about communication. We trying to do something which talks about communication whereas we are also learning how to communicate.

FG 4.3.10: It teaches you to understand the problem before solving it.

FG 4.8.11: I think it teaches us a lot, as we learn the expert system, we gain a lot; we gain communication, we improve our communication. It's like linking … with technology, so we learn a lot. We learn about context and all that. Ja. That is what I think.

Researcher: Someone else?

FG 4.2.12: We are all learning to be better communicators.

Researcher: How?

FG 4.2.13: By using the expert system.

Researcher: How? How is using or creating the expert system making you a better communicator?

FG 4.2.14: In the process of creating, me myself, I am also learning something about communication. Even though it doesn't work at the end of the day but at least I have learnt something about communication.

Researcher: How would it have been different if we had just stood in front of a class and just lectured to you? How would your understanding have been different?

FG 4.4.15: I think it wouldn't have had an effect, or much of an effect on us 'cause of the different personalities. I mean, if you tell someone that you should do this or that … it all depends on the kind of person that they are. Like we can't all communicate in the same way so if you create an expert system you are going to use you own views and how people like you would like to communicate. So then it helps you personally 'cause you are going to create something that is going to benefit you as an individual and you are going to understand it. Unlike if somebody tells you that you should communicate in this way. What if it's not something that you are comfortable with?

FG 4.3.16: When it is being lectured it becomes more easier because we are just looking what you are saying, what you are telling us, we are not applying it. When you start applying it, that's where it comes a problem 'cause we have to do exactly what you have just told us.

Researcher: You say a problem; so you are saying that it is not a good thing?

FG 4.3.17: No not actually that, I mean like when you lecturing that it becomes more easier because we see … we think it's simple but when it comes to us to apply it, the knowledge, it becomes a problem.

Researcher: And how does that improve your understanding? Or does it improve your understanding?

FG 4.3.18: It does improve it.

FG 4.4.19: For myself I prefer to do it practically instead of orally so practically I think I get a better understanding practising something, not reading it actually from the boo.

FG 4.5.20: And the fact that we come up with our own ideas, it makes us to think much better because we come up with our own ideas how the system experts should do the work.

FG 4.6.21: I think that when it comes to lecturing, like as we are people we are not the same. Others will find it interesting but others will not find it like a tool to lecture on. So like, umm, I prefer to hear somebody speaking not like to see words. I understand better when something is being spoken to me not like to read it. This expert system I think is going to give me a problem.

Researcher: Why?

FG 4.6.22: Because I will have to read the whole of the options like, as I've told you, if like he was using something like a voice, I could hear it, would be much better ja.

Researcher: OK, remember you are creating the expert system, so I am interested in seeing how the creation of the expert system is helping you to learn. Are you learning by creating it?

FG 4.6.23: Ja. Yes, it make me to become a logical thinker, think out of the box.

Researcher: OK, anyone else?

FG 4.7.24: Yes, as you said about the practical, I think the practical is going to be much easier for us 'cause we have to … you have to tell us and afterwards apply it. I think we will understand it … not each and every day the same, let's say where you end up last week, there is no process there. We have to do some practicals before we do the other expert system like we proceed. I think practicals will be much easier.

Researcher: What do you mean by practicals?

FG 4.7.25: Like not doing one thing each and every class.

Researcher: Do you mean change the problem, change the assignment?

FG 4.7.26: Ja I think ...You have to come with a new idea like when … all of us in the class one problem I think we will develop the …

Researcher: OK. All right now; I would like to get an explanation of what is not working for you here. I have already got a couple of insights like the time issue. I think that it has been quite disruptive because of all the holidays and the exam weeks and things like that. This has made it quite difficult from a continuity perspective, but besides that, what is working?

FG 4.2.27: We getting difficult to give the person like … if the person is asking questions from the expert system, to give the person the correct, exact answers that she wants. It becomes very difficult because in the expert system every question must also have a solution at the end so it becomes very difficult for us.

Researcher: But that is also part of the learning! That difficulty makes you think about it. Does it make you think about it because it is difficult?

FG 4.2.28: Yes, it is.

Researcher: Are you guys enjoying learning like this? Is it interesting for you?

FG 4.7.29: Yes, sort of.

Researcher: Why only sort of?

FG 4.7.30: Due to the fact of the time. When you get into a lab, ja we enjoy it but when we come out we've got to think about what we did and like just when we think about what we were doing at the lab we gather the fact that it needs more time like we have to sacrifice some of the time, some of our time. We come into lab late, we do the work and then… ja, but when we get into a lab, it's nice and then when you come out we have got to think about what we did there, eish, there we went wrong, there we were right, so.

Researcher: OK. Anyone else?

FG 4.2.31: I think if only we had access to the Internet, that's the other problem of the expert.

Researcher: Why to the Internet?

FG 4.2.32: Because the Internet is expensive. We don't have access in terms of practising.

Researcher: But why do you need the Internet to practice?

FG 4.2.33: Because CourseLab requires Internet in order to access it.

Researcher: No, it doesn't.

FG 4.2.34: Doesn't it? But it refuses to install in our personal PCs. It doesn't.

Researcher: Talk to me afterwards. Umm, OK, Anyone got any final thoughts about this whole thing? I didn't really get an answer from you guys when I asked whether you are enjoying the experience. Is this enjoyable? Is this interesting for you guys?

Group: Yes.

FG 4.6.35: Yes, it is enjoyable. It's kind of interesting.

Researcher: Any you guys feel as though it is constructive, that you are learning something about communication?

Group: Yes.

Researcher: In what way would that be different from just being lectured to you or if it was just in a handout?

Group: Yes.

Researcher: Can I ask just one last question? Why is that?

FG 4.7.36: Mainly I think that it is because it is not every day that we get a chance to link communication with technology. So we enjoy that part, due to the fact that we are doing IT also, ja.

FG 4.1.37: I agree with him; I agree with him. And also incorporate technology into your everyday life.

Researcher: So it makes the learning a little bit more real?

FG 4.1.38: Unlike learning all about computers and you are not applying it to your everyday life then you just learn about it, read about it and then you just move on. But then if it is something that you are going to use every day, or like regularly, in your thing, then it gets more interesting because you know the whole purpose of IT. Like if I am studying IT then my whole purpose is … 'cause it's not just like some random thing, like you just study computers and move you move on. It's going to be an important …; it's going to play an important role in your life, ja. Like almost every aspect of our lives is based on technology, cell phones, the bank, everything, like TV, everything is technology, so ja I think it helps a lot.

Researcher: Now really my last question. What should be done differently?

FG 4.1.39: More time definitely; I would prefer more time.

Researcher: More lab time or more time generally?

FG 4.1.40: More time to do the project because when you are under pressure you don't get the time to actually enjoy something. 'Cause you want to get to the deadline and you miss out on the whole experience.

Because you just want to get to the finish line without enjoying the whole process of it; yes.

Researcher: And, anything else? What else should be done differently? The software? Is the software working?

Group: Ja, the software is fine.

FG 4.2.41: Easy to use; it's not complicated.

Researcher: Anyone got something to say?

FG 4.7.42: At the end we would really like to see your expert system, ja. The one that you did … like this one is the one, we would like to see how did you do it, how did you go for it.

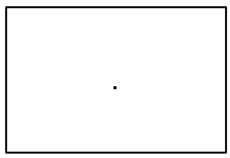
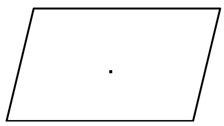
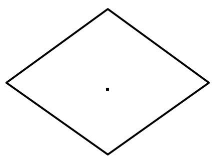
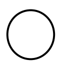
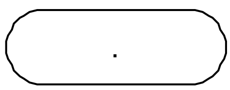
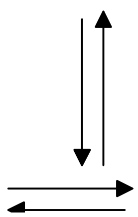
FG 4.2.43: That's not thin, like you always tell us in class.

Researcher: Somebody else? All right. Thanks guys.

Addendum H

Getting to know flow diagrams and IF THEN statements

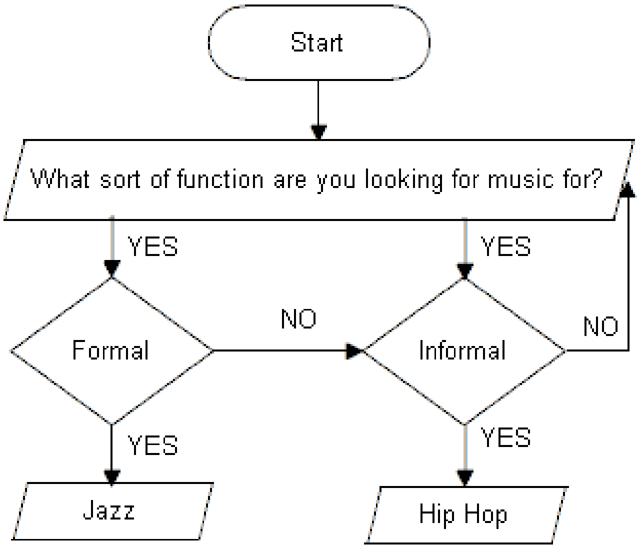
The following symbols are used in the examples and exercises that follow. It is important that you clearly understand how they are used as they will help you to represent the logic of your expert system.

	**Process** This symbol indicates any type of processing that needs to happen. For example, 2 numbers being added together (add 3 + 6) or an item added to a list (add 'Ford' to the list of cars), etc.
	**Input/Output** This symbol is used for any input or output operation and indicates when the computer needs to obtain information or when it sends information out. For example, get an option from the user (i.e. the user is required to select an item from a list of options, etc.).
	**Decision** This symbol is used to ask a question that can be answered with a 'Yes' or 'No' or a 'True' or 'False'.
	**Connector** This symbol is used to join parts of a program and can be useful when the program becomes too long and is spread over more than one page.
	**Terminal** This symbol indicates the start and the end of a program.
	**Flow lines** These symbols indicate the direction of flow and connect the above symbols to one another.

The following examples and exercise have been designed to make you familiar with the way in which decisions structures are represented in the form of flow-diagrams and IF THEN statements.

Let's start by looking at a very simple example: *Choosing the most appropriate music for a function*

A flow- diagram that outlines the logic used to decide what music is most appropriate for a particular function could look like the one below.



The same sort of decision structure used in the diagram above could be expressed in the form of a simple IF THEN statement such as the one below.

IF Formal THEN
    Jazz is appropriate
IF Informal THEN
    Hip Hop is appropriate

Exercise 1

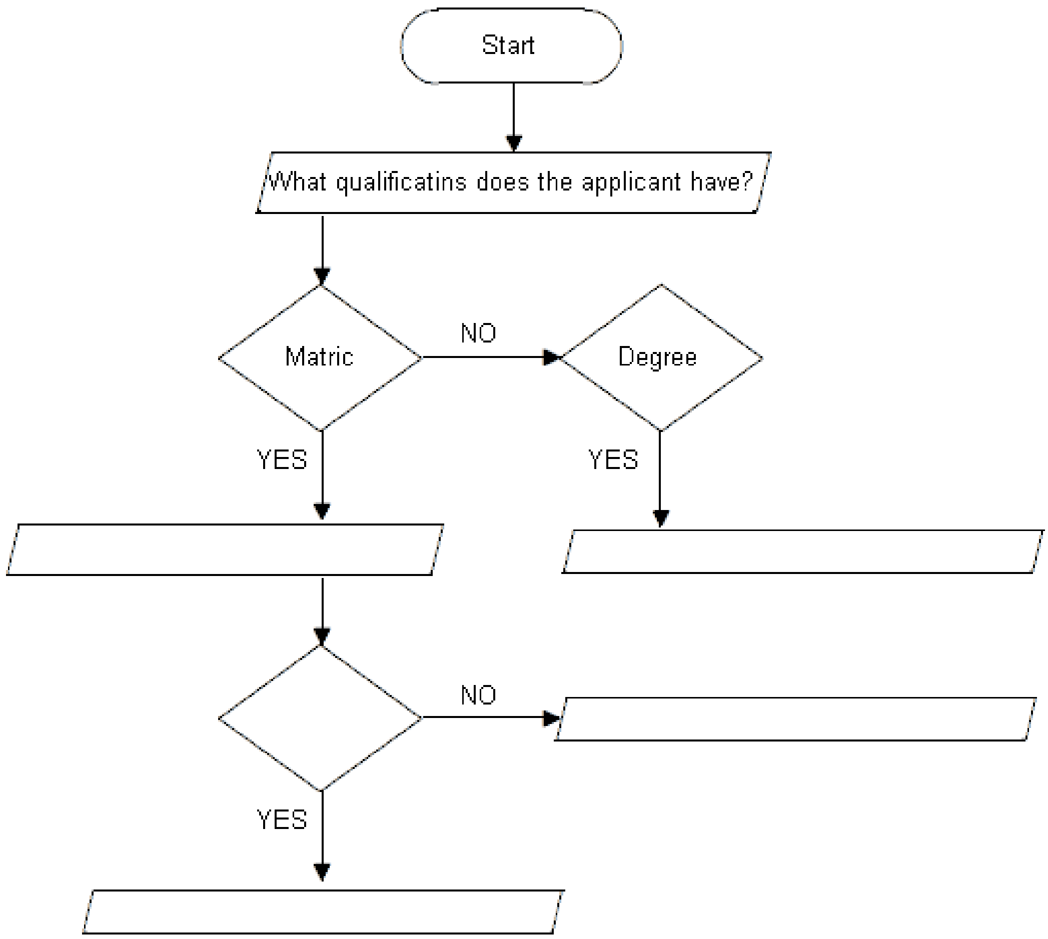
Represent the following IF THEN statement using a flow-diagram such as the one above:

IF the object has corners THEN
    it is a box
IF the object is round THEN
    it is a ball

Exercise 2

Complete the flow-diagram below representing the following IF THEN statement:

IF candidate has a matriculation certificate THEN
IF the candidate has experience THEN
send an invitation letter for an interview
IF the candidate has no experience THEN
send a letter declining application
IF candidate has degree THEN
send an invitation letter for an interview



Exercise 3

1. In your groups, think of a simple real world problem that would need to be solved by selecting a series of options similar to the examples used above.

2. Represent this problem using an IF THEN statement.

3. Represent this problem using a flow-diagram similar to the ones used above.

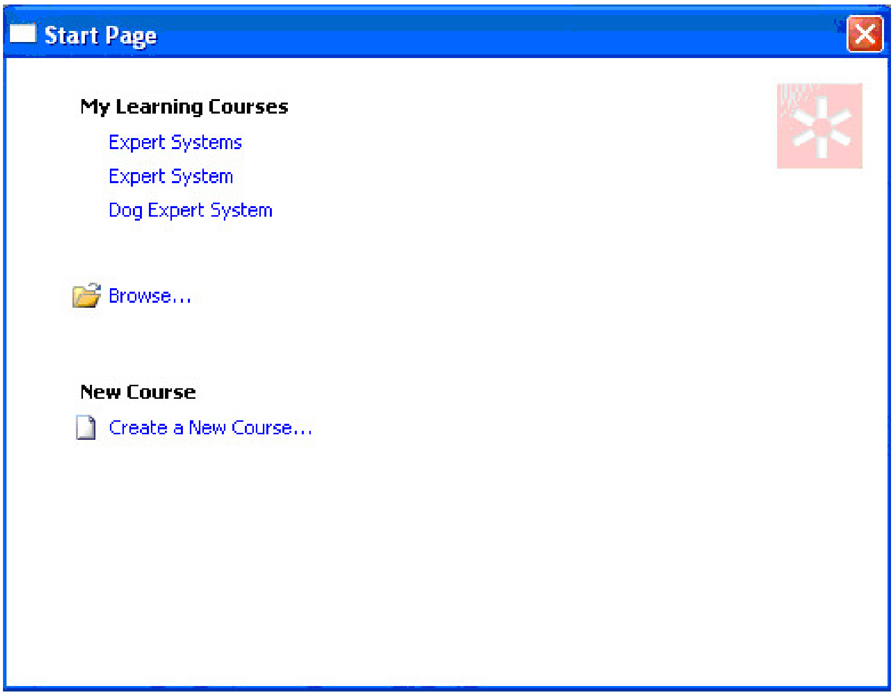
Addendum I

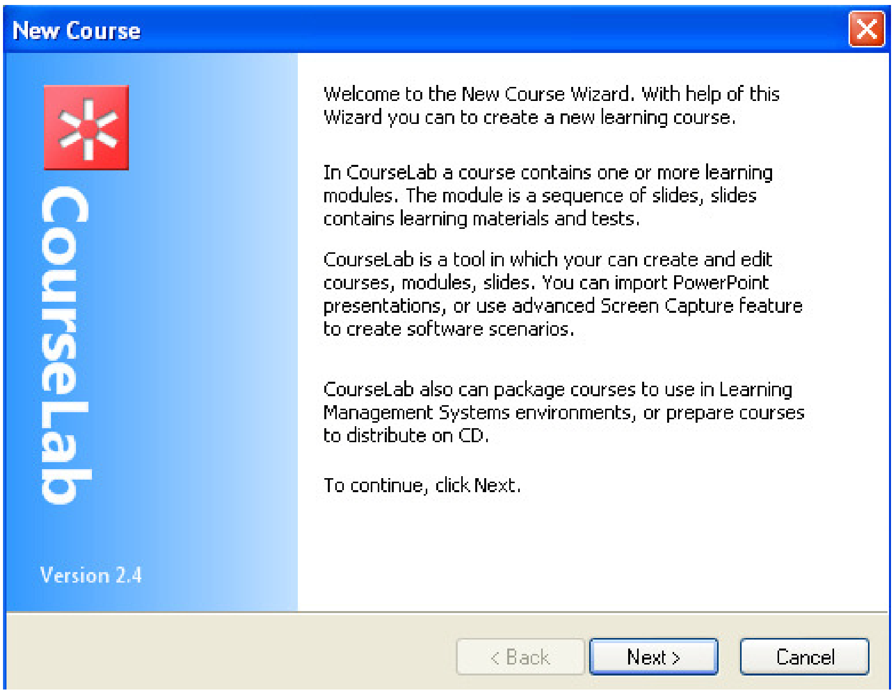
Step by step guide to creating an expert system using CourseLab

The basics of using CourseLab

Step 1 Open CourseLab by clicking on its desktop icon.

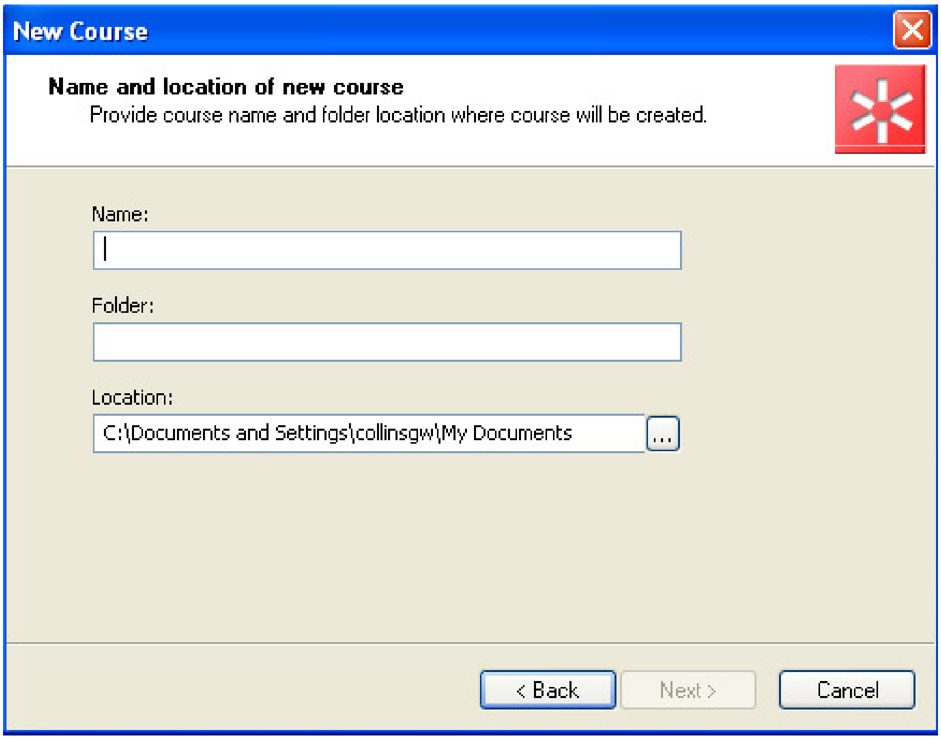
Step 2 Click '**Create a New Course**'. This will open the 'New Course Wizard'. Click 'Next'.



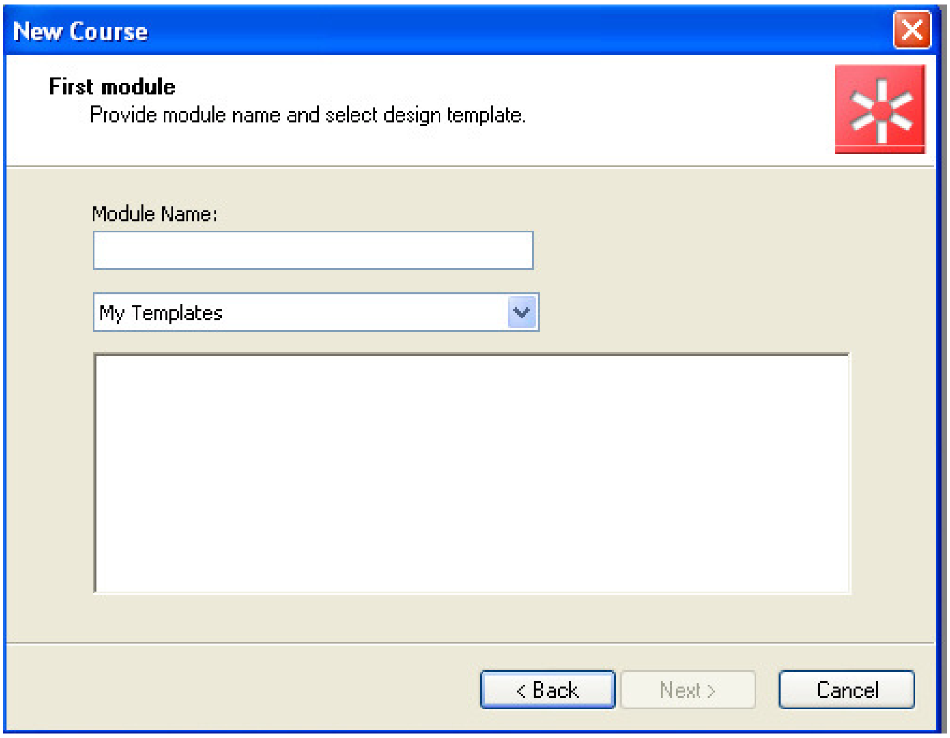


Step 3 Enter a name and location for your 'New Course' (Remember you are not really creating a course; we are simply using this teaching software as a tool to create an expert system).

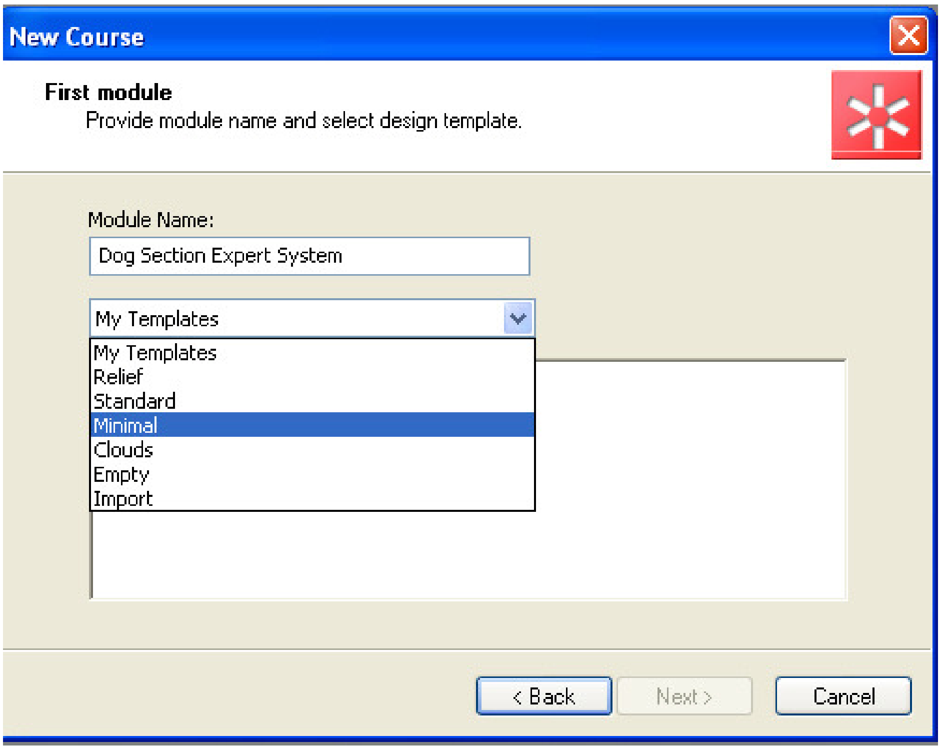
Step 4 Enter a Name and Location for your 'New Course' (actually your collection of expert systems). Then click 'Next'.
A suggestion is: 'Name='Expert Systems' & Location = 'Expert System'.

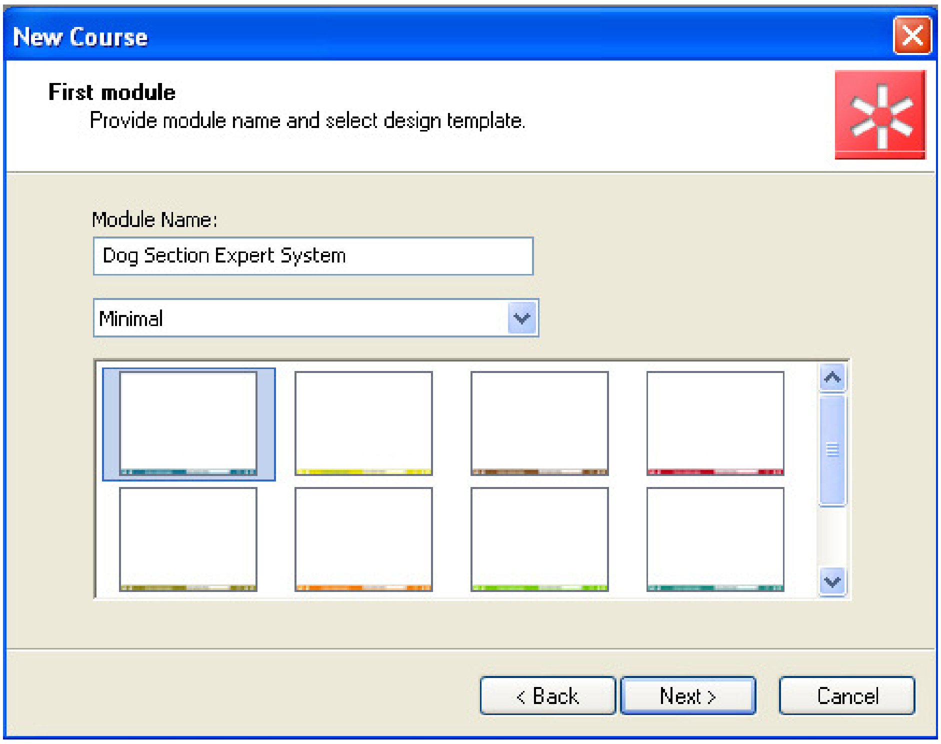


Step 5 Enter a 'Module Name' (Actually the name of your first expert system) Then click 'Next'.



Step 6 Choose a 'Design Template'.
Suggestion: Choose one of the simplest ones, 'Minimal'.
Then click 'Next' & 'Finish'.

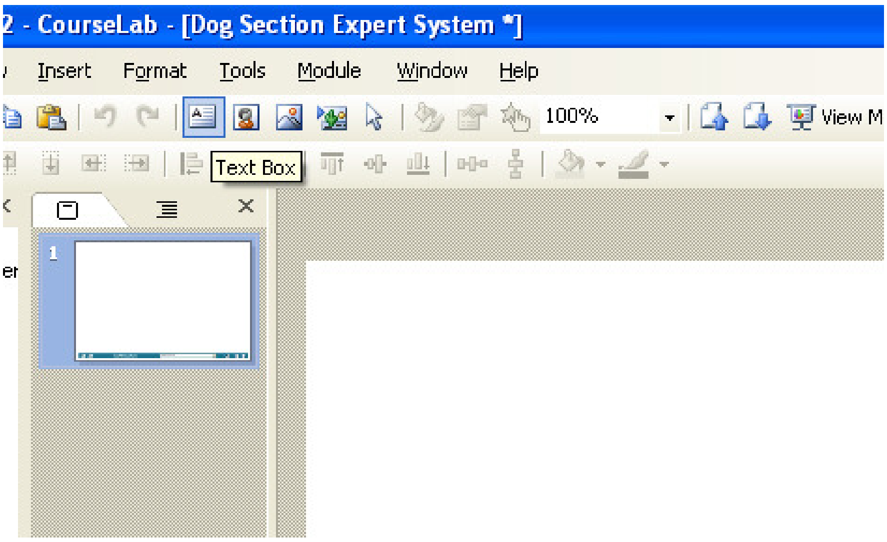




You now have a blank platform on which you can create an expert system.

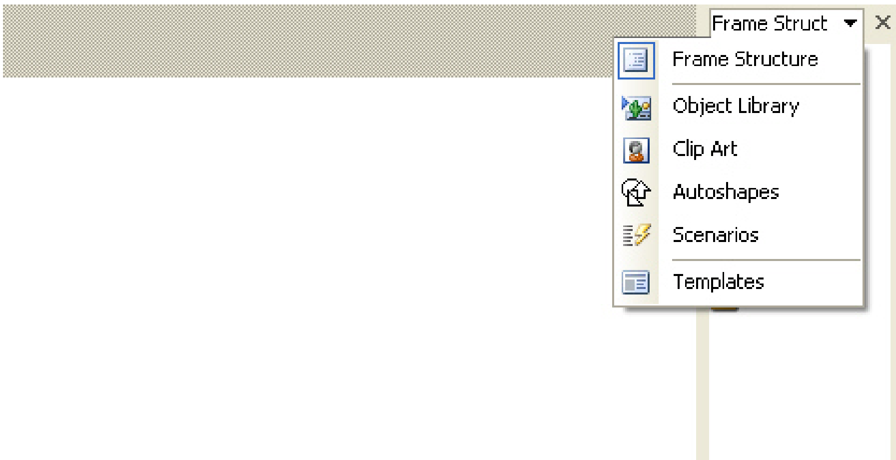
Creating the expert system:

Step 1 Remember an expert system guides the non- expert user by asking questions. One of the simplest ways you can allow the expert system to 'ask a question' is by typing the question in a 'Textbox' that we put on the screen. Simply click on the following icon in the task bar. A textbox will appear on you blank template; you can now drag the textbox to where you want it.

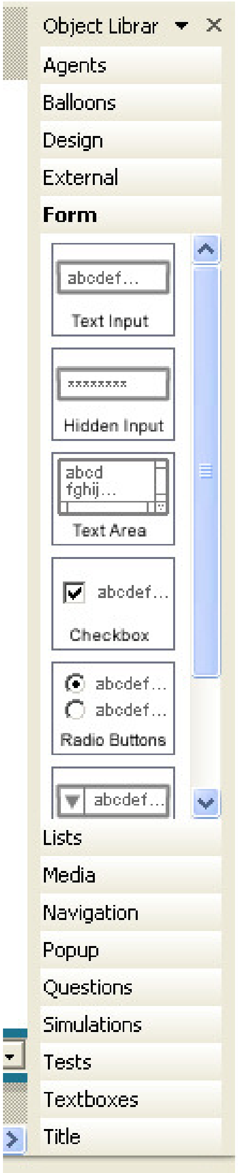


Step 2 Double-click on the textbox in order to type in an appropriate question.

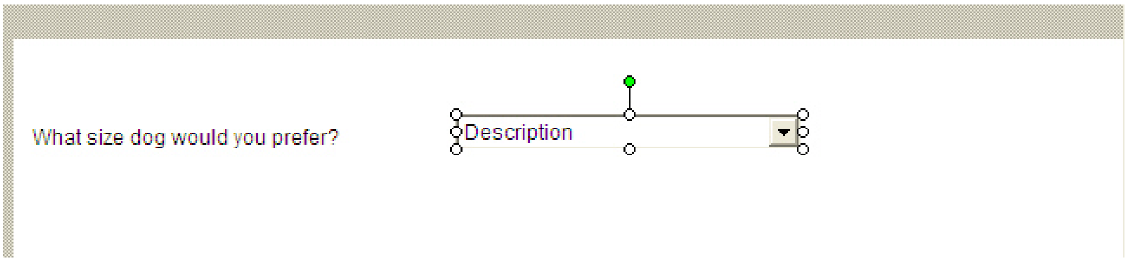
Step 3 Now you have to create a way for the user to respond to the question. One of the easiest ways is by means of a dropdown list that contains logical or appropriate options in it. A dropdown list is an 'Object' that is part of a 'Form'. Click on the dropdown arrow next to 'Frame Structure' near the top right of your screen.



Then click on 'Object Library' and then on 'Form'. You will now see all the 'Form Objects' that can be used in 'CourseLab'.

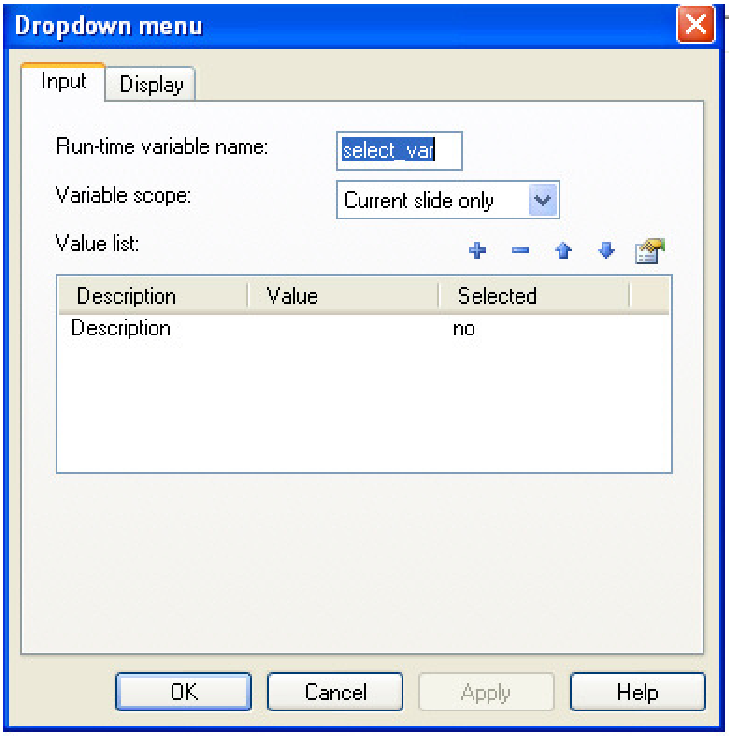


Select the ‘Dropdown list’ by clicking on it and dragging it onto your slide.



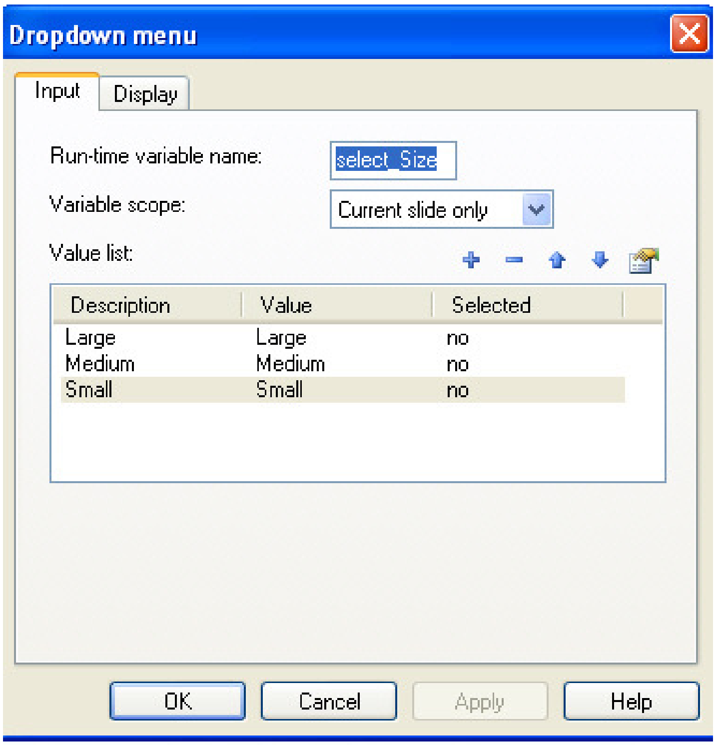
Step 4 Double-click on the ‘Dropdown list’; this will open its ‘Properties’ dialogue box. You can now give it a ‘Runtime variable name’ and add items that will appear in its dropdown list.

Remember the 'Runtime Variable name' will be used to refer to that particular 'Object' when you start to do your programming.
The items in the 'Value list' are those that appear when the user clicks on the dropdown arrow next to the box. Note that you need to add both a 'Description' and a 'Value' to the items in the Value list.

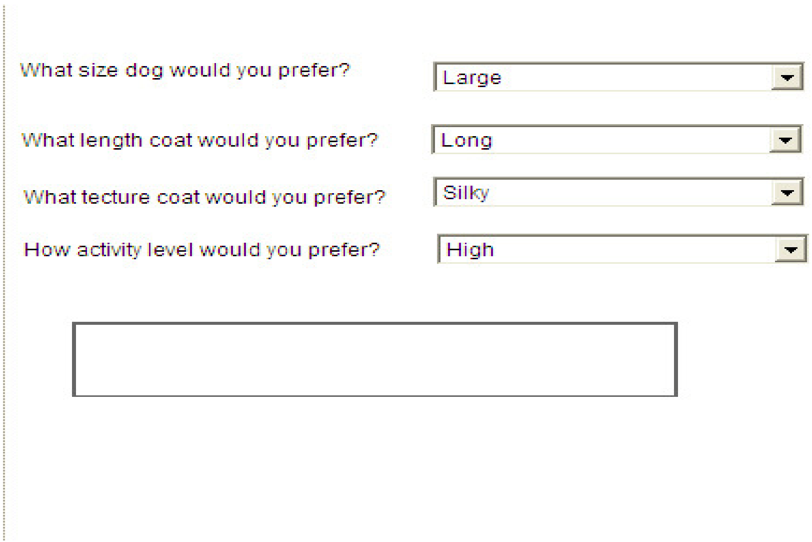


Step 5 Repeat steps 4 and 5 until you have added all the necessary questions and dropdown lists to the slide.

Step 6 You now need to provide your program with a way of communicating the suggested solution to the user. One way to do this is to put a 'Text input' box on the slide. To do this you select the 'Text Input' box from the object library and drag it onto your slide. Give it a 'Runtime Variable name' by double-clicking on it and opening its 'Properties' dialogue box. You add items to the dropdown box menu by clicking on the **+** symbol and then double-clicking on the item in the 'Value list'.

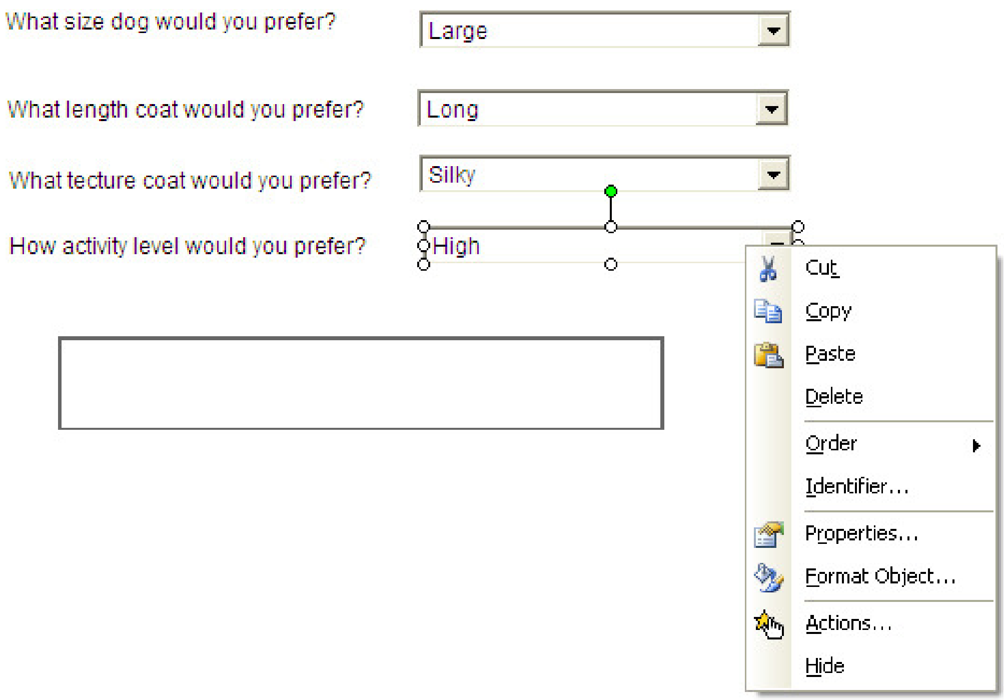


Congratulations! You have created the user interface for your expert system. It is now time to do some simple programming:



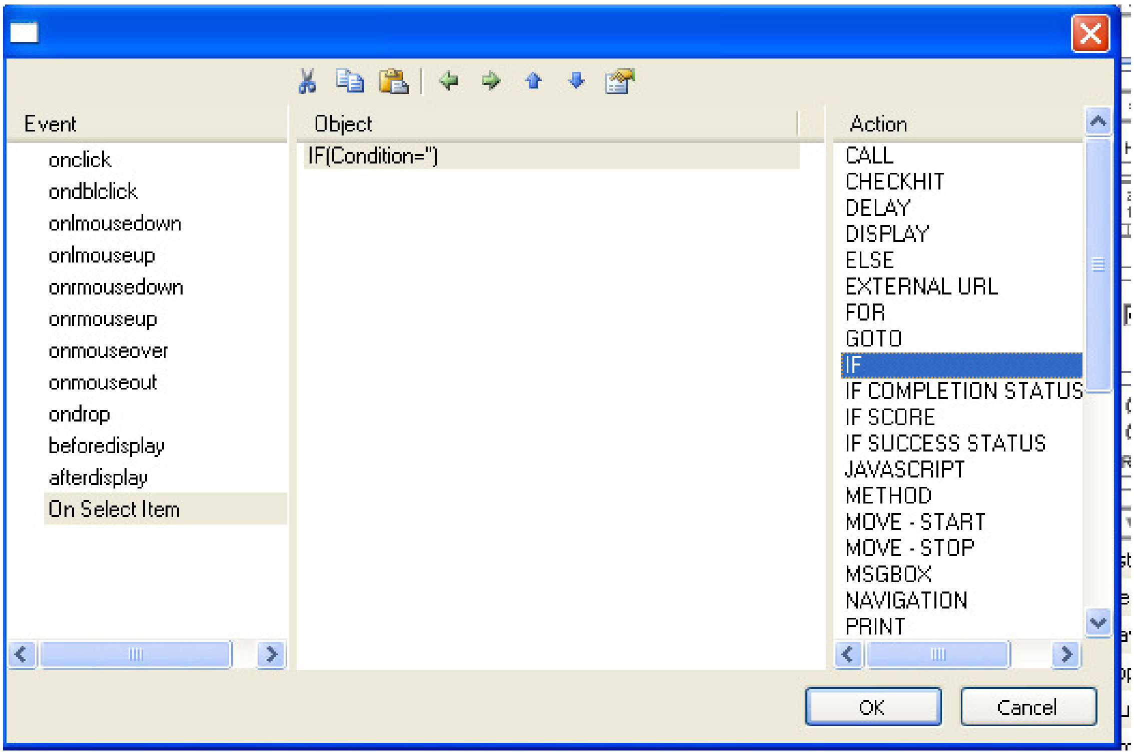
Creating the knowledge base:

Step 1 In computer programming an 'Event' initiates the execution of programming commands. A suitable event for your purpose would be when the user selects an option from the last dropdown list on the slide. Select the last dropdown box on the slide and right-click. Select 'Actions.' This will open a dialogue box that has all the 'Events' associated with the object on the left and all 'Actions' on the right.

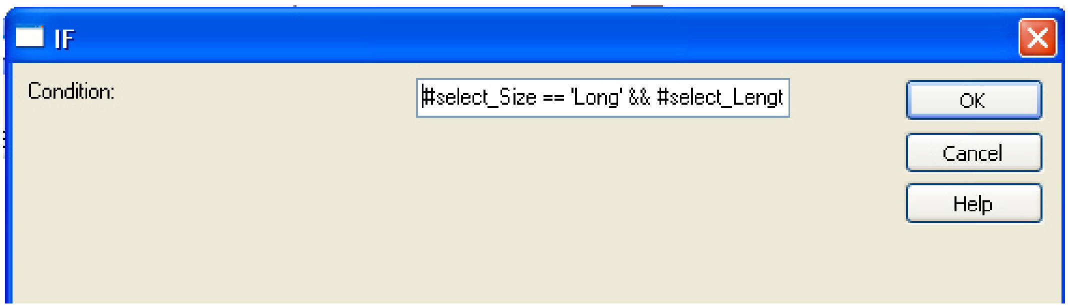


Step 2 Select the 'On select Item' event from the list of events on the left by single-clicking on that option.

Step 3 Select 'If' from the list of actions on the right by double-clicking on 'If'.



Step 4 Now double-click on the 'IF(Condition)' statement in the 'Object' section of the dialogue box. This will allow you to specify the conditions that must be met for a certain action to take place. Type in the condition using '==' to indicate '=' and '&&' to indicate 'and'. If you want to indicate an object you need to use the symbol '#' before that object's name (e.g. #select_Dog_Size).
An example of a condition statement that uses the correct syntax would be: #select_Dog_Size == 'Large' && #select_Coat_Length == 'Long'.



Step 5 Once you have specified the condition that needs to be met it is time to indicate what action needs to take place if this condition is met. An action associated with a particular object is called a 'Method'. We want the 'Text input field' to display the suggested solution to a problem so you want to set its value once a certain condition is met. To do this, select 'method' from the action list. The statement 'METHOD(Object =,"Method")' appears in the Object section of the Actions dialogue box.

Step 6 Double-click on the ‘METHOD(Object =,”Method”)’ statement to open the Method dialogue box. Here you need to specify the object that must do something or change when the condition is met and you must indicate what method that is associated with a specific object is applicable. Select the appropriate object from the ‘Object’ list. Select ‘SetValue’ from the Method list and then input the sentence that you want to be displayed when the specified condition is met.

Addendum J

Common errors encountered when building an expert system using CourseLab

- Remember that CourseLab is **case sensitive**.
- Remember to use '**value**' in you condition statements and not '**description**' (**Description** is what will appear only in the dropdown list; **value** is what is evaluated in the condition statement).
- Remember to use '**runtime variable name**' when you want to refer to a specific '**object**'.
- Remember to use '**#**' before the '**runtime variable name**' in your condition statements, e.g**. #select_qulification == 'matric' && # select_experience == 'yes'**.
- Remember to select the correct '**event**' for an object. For a drop down list the most appropriate event would be '**On select item**' because the execution of the program would only be triggered once the user has selected a specific option.
- Remember to **indent** your method statement to make it dependent on the **IF** condition.

Check list

- If your expert system does not work, go back and check the following:
    - Check that the spelling that you have used for all '**objects**', '**runtime variables**' and '**values**' is consistent.
    - Make sure that the case (i.e. upper or lower) you used when referring to '**objects**', '**runtime variables**' and '**values**' is consistent.
    - Make sure you have chosen the correct '**event**' for the applicable object.
    - Make sure that you have chosen the correct '**object**' to display the advice or solution to you problem.

- Make sure that you have chosen the correct '**method'** associated with that object (i.e. if you have chosen an '**input textbox**' to display your solution/advice, then the correct method would be '**setvalue'**).
- Make sure that you have indented '**method**' so that it would be dependent on the IF condition being met.
  - E.g. **IF (Condition=#select_qualification == 'Matric' && …)**

    METHOD(Object = 'OBJ_11', Method='setvalue')

Addendum K

Ethical clearance certificate

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Faculty of Education

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	**CLEARANCE NUMBER :**	SM 10/10/02
DEGREE AND PROJECT	PhD Information communication technology as a cognitive tool to facilitate higher-order thinking	
INVESTIGATOR(S)	Gary Wayne Collins	
DEPARTMENT	Science, Mathematics and Technology Education	
DATE CONSIDERED	09 April 2012	
DECISION OF THE COMMITTEE	APPROVED	

Please note:
For Masters applications, ethical clearance is valid for 2 years
For PhD applications, ethical clearnace is valid for 3 years.

CHAIRPERSON OF ETHICS COMMITTEE	Prof L Ebersohn
DATE	09 April 2012
CC	Jeannie Beukes Prof. J.G. Knoetze

This ethical clearance certificate is issued subject to the following conditions:

1. A signed personal declaration of responsibility
2. If the research question changes significantly so as to alter the nature of the study, a new application for ethical clearance must be submitted
3. It remains the students' responsibility to ensure that all the necessary forms for informed consent are kept for future queries.

Please quote the clearance number in all enquiries.