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

<table>
<tr><th>Date of session</th><th>Discussion / Programme</th><th>Substantive themes</th></tr>
<tr><td>20 January 2011</td><td>• Introduction to the design process</td><td>• No substantive themes emerged; only initial impressions of the research undertaking were obtained.</td></tr>
<tr><td>2 February 2011</td><td>• Presented the tentative design to the design team.
• This included:
  o Demonstration of a functional expert system.
  o Algorithmic representation of the expert system.
  o Handout of step by step guide to developing an expert system.
  o Paper-based exercises.</td><td>• 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.
  o 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:
  o Cannot stand alone.
  o Language must be accessible to the students.
  o Terms need to be defined in a simple way.
  o Including more graphics may be useful.
  o Some students may move too far ahead or lag behind when working through the paper-based exercises and tutorials.
  o 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:
  o They can serve as a good reference for later that could jog the students' memory.</td></tr>
</table>

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.
		    o Provided a natural progression from one step to another (Conceptual understanding to externalisation of that understanding).
		    o Students need not all think about what questions to ask (they are already there) (made gap more digestible).
		    o 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.
		    o Negotiate solutions to problems among themselves.
		    o 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.
		    o 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.
		    o Could constantly refer to video for more info.
		    o 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.

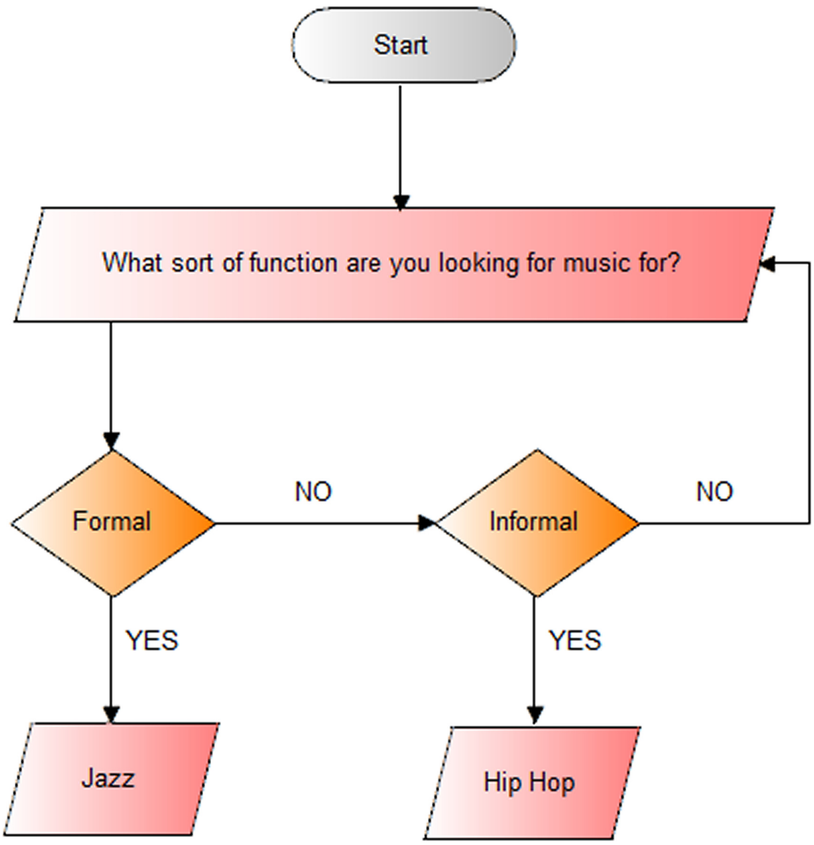

Figure 4.1 An example of a simple decision structure

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

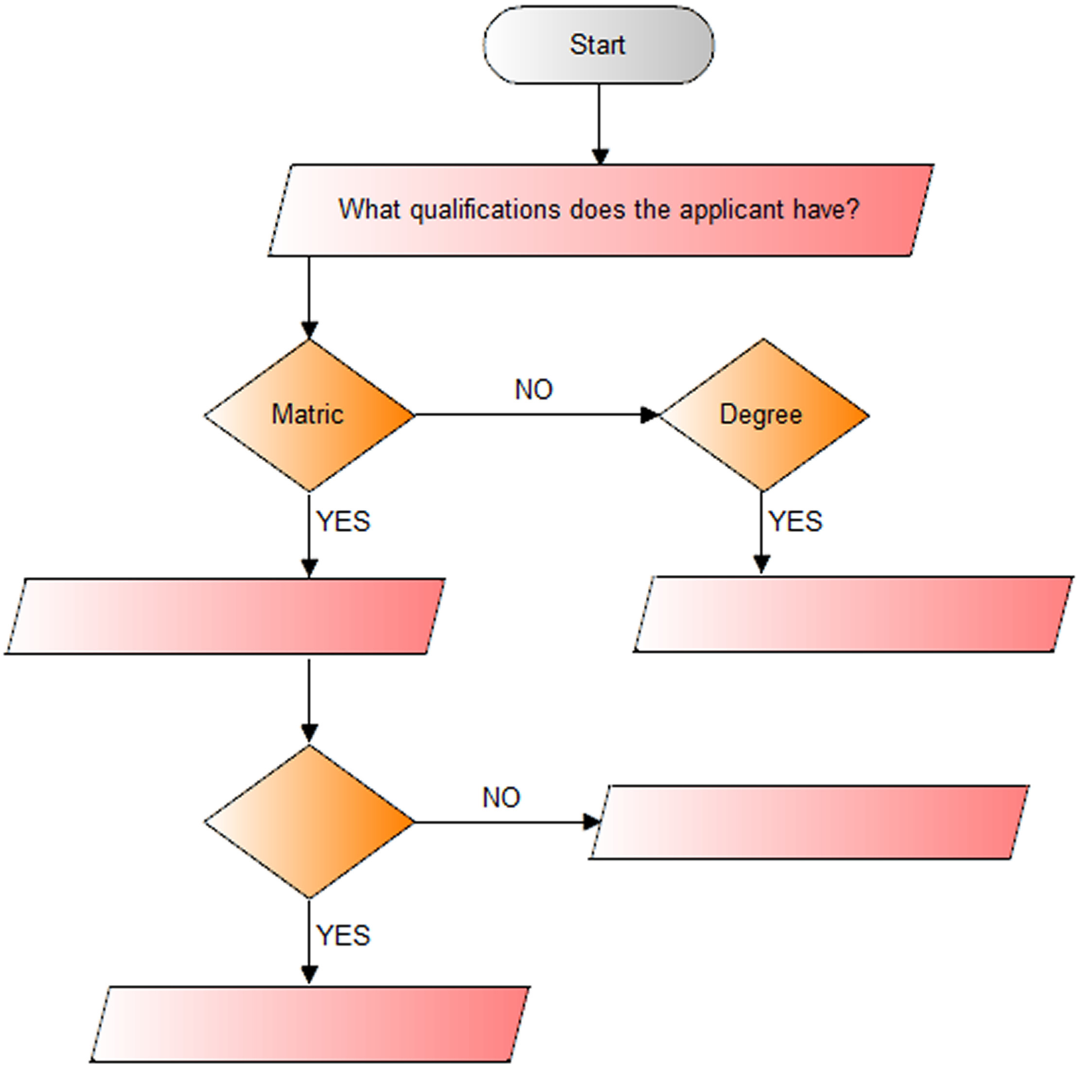

Figure 4.2 A flow-diagram representing an invitation to a job interview decision structure

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

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