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**USE OF CONSTRUCTIVISM IN THE DEVELOPMENT AND  
EVALUATION OF AN EDUCATIONAL GAME  
ENVIRONMENT**

By

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Submitted in fulfilment of the requirements for the degree of  
**Doctor of Philosophy in Science**

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December 2004

BRN 441473

HC 05/04785

AV05/682

**PREFACE**

The experimental work described in this thesis was carried out at the School of Life and Environmental Sciences at the University of KwaZulu-Natal, Durban, from February 2000 to December 2004, under the supervision of Prof. A. Amory.

These studies represent original work from the author and have not otherwise been submitted in any form for any degree or diploma to any tertiary institution. Where use has been made of the work of others it is duly acknowledged in the text.



We hereby certify that the above statement is correct

Robert Seagram  
December 2004

Prof. A. Amory  
(SUPERVISOR)

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## ACKNOWLEDGEMENTS

My sincerest thanks must go to a number of people for the wonderful support I have received during this study.

Firstly I am extremely grateful to my supervisor, Professor Alan Amory, for the opportunity he afforded me in being part of this research project. Thank you for always being fair and just and for always looking out for the best interests of your students.

My sincere thanks also go to the National Research Foundation for supporting this project.

I would also like to thank Tarryn Nicholson for her words of encouragement, her unfailing word, her much needed help and unfaltering faith in me. Thank you for all your advice and for all the sacrifices you've had to make for this study to be written. I am truly grateful.

To the crew in the lab, most notably to David Baxter (Spot), Paul Rodda (Headlock), Thato Foko (Debra) and Reishin (Rasheed), thank you for your interest and constant helpful advice in the design of this game. Your collective input has given me a wealth of knowledge and has stood me in good stead. I would also like to extend my sincere thanks to Tasmin Raynor and John van der Ruit for the immense effort they put into this project, as well as Steven Yates for his time and effort in proof-reading most of this script.

Sincere thanks also go to Miles Warrington and Phillip Tembu for the music which was designed specifically for this portal and for the painstaking care that was taken in designing musical themes which add another dimension to the gameplayers experience of this portal.

Last, but not least, a special thanks to my family. Thank you all for being so supportive over the years and for always being there for me. Your support and love is truly appreciated.



## ABSTRACT

Formal learning contexts often present information to learners in an inert and highly abstract form, making it unlikely that learners would ever use this information in their every-day lives. Learners do, however, show a greater propensity for retaining information that is seen as having relevance in their lives. Constructivism is an educational paradigm that has gained popularity amongst educationists. The core tenet of this paradigm is that learners learn through interaction with their environment and that all knowledge construction is based on previous life experience. Information that is presented to learners in a contextualised form not only has a better chance of being retained in long-term memory, but also has a greater likelihood of being applied in relevant life situations. This publication deals with the research, design and delivery of important information concerning diseases that have a major impact in Southern Africa. Firstly, learners at the University of Natal, Durban were polled for their existing knowledge concerning four widespread diseases, namely HIV/AIDS, tuberculosis, malaria and cancer. Aspects of these diseases where learners demonstrated a low level of awareness were defined as the primary learning objectives for an educational 3D- immersive microworld. Areas of knowledge concerning the transmission, symptomatic expression, biology and prevention of these diseases were generally not well represented in the learner sample. Hence, information regarding these aspects is presented to learners in a contextualised form within the microworld. Motivation for learners to play in this microworld is provided by a storyline that was researched and written for the portal. In addition, the model used in the storyline design was evaluated for its effectiveness as a tool to be used in the planning of future educational games. A model, the Puzzle Process model, was proposed to inform the design of puzzle interfaces for these types of interactive learning environments, and puzzle interfaces were designed for the virtual environment according to the model guidelines. The learning environment was tested as part of the formative evaluation with a small sample of learners. The testing process made use of both quantitative and qualitative methodologies to evaluate the effectiveness of the learning environment as a possible learning tool. Comparison of pre- and post-gameplay questionnaires showed that learners gained a more indepth and richer understanding of the topics being dealt with in the portal. In particular, the puzzle objects situated in the environment stimulated learners to negotiate meanings for the puzzle interfaces and, in the process, encouraged learners to discuss the topic being dealt with. Results from this study also show that the longer learners discussed and negotiated a certain knowledge domain, the greater their increase in richness of information was for that knowledge domain after gameplay. These results highlight the importance of social dialogue in the knowledge construction process and suggest that environments like these have great potential based on their ability to encourage learners to talk to one another and their facilitators while negotiating mutually acceptable knowledge. The original Puzzle Process model, as well as the Game Achievement model and the Game Object model were modified to account for the need for social dialogue and content. These more comprehensive models are instrumental for use in future virtual world environment design.

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## CHAPTER 1

### LITERATURE REVIEW

#### 1.1 Introduction

Education is changing in that it is becoming less teacher, and more learner-centred in nature (Tansey and Unwin, 1969). For over a century teaching has involved the didactic process where the teacher tells the student information (Amory, 1997) – there is a one-way transfer of information and whatever the teacher says is accepted at face value. Here the teacher is the authority being, the all-knowing. Yet as young children we learn from our own experience – we learn through ‘play’ and this ‘play’ performs important roles in the psychological, social and intellectual development of children (Rieber, 1996a). This causes a dichotomy between the conditions optimal for learning and the conditions still prevailing in many educational settings to date.

Modern educational theories have started calling for a change in the way learners experience their education. Teachers are moving more from the didactic role towards the role as facilitator. As facilitators, teachers can act as guides and collaborators, effectively making learners the centre of the learning environment (Reeves, 1995).

Constructivism lends itself particularly well to learning environments in which the teacher is the facilitator and in which the learner is actively engaged in the learning process (Phillips, 2000). In this paradigm information is not simply transmitted from one to another, but is rather built up, or “constructed”, by the learner themselves (Driver *et al.*, 1994).

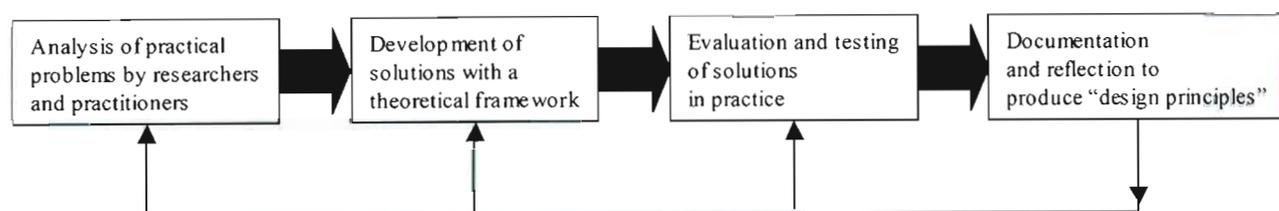
Although the earlier use of technology has, in some cases, shown no effect on the ability of students to understand new concepts (Amory, 1997), the mode of information delivery is important in determining the success of the medium. Expanding on the first concept of a microworld (Papert, 1981), multimedia today can provide far more sophisticated microworlds geared to better educating learners (Boyle, 1997). These learning environments can now take the form of fully immersive and contextualised 3-dimensional computer microworlds in which learners can fully explore a specific knowledge domain (Boyle, 1997).

#### 1.2 Development research

Van den Akker (1999; cited Reeves and Hedberg, 2003) espouses a form of inquiry referred to as ‘development research’. This form of research is well suited to the design of interactive learning

environments as it makes contributions on both the theory and practical aspects of the research process (van den Akker, 1999). Methods employed in this theoretical framework not only yield results applicable in the immediate context of the research but also contribute to the long-term development of understanding with more general design principles (Reeves and Hedberg, 2003). None of the methods evident in this research method are unique to development research, but the philosophical framework within which these methods are applied is fundamentally different to other types of research (e.g. empirical research) (Reeves and Hedberg, 2003).

Figure 1.1 details the process of development research and highlights the need for both practical and theoretical research outcomes. The process is also seen as iterative in that formative evaluation is used to continually improve the design process.



**Figure 1.1** Model showing the developmental research approach to learning technology. Taken from: Reeves and Hedberg (2003); p. 274.

The development research framework was applied in this study, and the work that was undertaken has been linked to this model throughout. This study essentially operated on two different levels, with the practical aspect relating directly to the realisation of a game that would address a lack of knowledge in a specific domain, and a more generalised basic research pertaining to the improvement of interactive learning environment design with implications for educational design in general.

In this chapter, the analysis of practical problems facing educational technology design will be elucidated. The factors known to be important in learning will be discussed, problems with current didactic education delivery modes will be highlighted and educational technology will be discussed as a potential tool for addressing these concerns. The theoretical framework that was adopted for this study will be described and the design parameters within this framework will be elucidated. Finally, the structure to be followed in the dissertation will be described.

### 1.3 Cognition

The process of learning implies more than simply accessing information (Richards *et al.*, 1997). It is therefore important for educational environments to account for the mechanisms that allow learners to incorporate information into their cognitive processes (Richards *et al.*, 1997). Cognitive processes can be defined as the patterns of action that underlie specific acts of intelligence (Kearsley, 1994).

#### 1.3.1 Acquiring information

There are several very important concepts we know to be true about internal cognitive processes. Firstly, memory consists of a sensory area, short-term storage, and long-term storage. For processing information in the sensory memory, learners should be able to focus their attention and minimise excessive disturbance. This is because learners can only transfer a small amount of what they perceive to short-term memory (Miller, 1956; Grabowski and Aggen, 1994). Learners must also manipulate the information in short-term memory before it can transfer to long-term memory. Secondly, the learner must actively process information in order for it to be shifted first from sensory to short-term memory, and again to long-term memory. Thirdly, the memory consists of an extensive networking of prior knowledge. For permanent learning to take place, these existing networks need to be tapped. Further, for deeper information processing to occur, new networks need to be formed from old ones through analogical thought (Miller, 1956).

Long-term memory has two major facets: shallow processing and deep processing (Grabowski and Aggen, 1994). Once information is perceived, it must be reorganised in a way that will facilitate the locking of this information into long-term memory. Rehearsal, paraphrasing, imaging and mnemonics are all cognitive strategies that can be used to record this information in long-term memory (Miller, 1956, Grabowski and Aggen, 1994). For more resistant storage in the long-term memory (deep processing) the information should be related to a network of prior experiences (Grabowski and Aggen, 1994).

Content can be integrated into existing knowledge structures through assimilation and analogical reasoning. Assimilation is the integration of new information and related existing knowledge, while analogical reasoning ties new concepts to other concepts using structural relationships (Grabowski and Aggen, 1994).

In order to provide understanding in the longer term (deep processing) the process of reflection needs to be initiated in users (Richards *et al.*, 1997). Reflection implies an interaction with information without which knowledge transfer could not take place (Richards *et al.*, 1997). However, not all information that passes through short-term memory is stored in the long-term memory (Kozma, 1987). The current theory is that the

longer information is stored in the short-term memory, or the longer it is transformed there, the more likely it will enter long-term memory (Kozma, 1987). This knowledge then becomes permanent in the long-term memory, only becoming inaccessible through ineffective retrieval from memory (Kozma, 1987). Much of what goes on in learning is determined by the cognitive strategies the learner uses. These strategies are the actions of the learner that obtain additional information (either from the environment or long-term memory), manipulate it, and organise and structure it so that it enters the long-term memory in a retrievable form (Kozma, 1987). Cognitive strategies include scanning, searching, questioning, chunking, hypothesis generation and decision-making (Flavell, 1979; Kozma, 1987, Hill and Hannafin, 1997). These processes are automatic for some learners, but they are not automatic for inefficient or inexperienced learners (Kozma, 1987).

### 1.3.2 Learning in context

Research has shown that many differences exist between formal and informal learning (Resnick, 1987). Formal learning emphasises abstract and systematic problem-solving strategies (Rogoff, 1984). Formal, bottom-up methods incorporating these strategies are not often used by learners, and are rather displaced by more practical and opportunistic strategies that can be used in everyday circumstances (Rogoff, 1984).

Norman (1993) makes a distinction between two kinds of cognition: experiential and reflective cognition. Experiential cognition is a “state in which we perceive and react to the events around us, efficiently and effortlessly” (Norman, 1993: p. 16). In contrast, reflective cognition demands deliberate thought and reasoning which occurs with time (Rieber, 1996a). These two forms of cognition are not mutually exclusive as we use both every day. Basically, “Tacit understanding can be viewed as one outcome of experience, whereas explicit understanding is the outcome of reflection.” (Rieber, 1996a: p. 20). Tacit knowledge is usually defined as knowledge of which we are unaware and which remains unanalysed by an individual (Alexander, Schallert & Hare, 1991; Rieber, 1996a). Many learners have difficulties applying concepts learned in formal learning environments to everyday situations (Carraher, Carraher and Schliemann, 1985; Lave, 1979; Perkins, 1985). This problem is a result of the decontextualised nature of formal learning experiences (Bransford *et al.*, 1992), which promote separating the facts from the contexts in which they derive their meaning (Cognition and Technology Group at Vanderbilt, 1990). Highly decontextualised and simplified knowledge is incomplete and naive (Spiro, Feltovich, Jacobson, & Coulson, 1991).

The importance of context is paramount when encouraging learners to make connections between knowledge, skill and experience (Choi and Hannafin, 1995; Bransford *et al.*, 1992). According to Rogoff (1984), context can be defined as the social circumstance in which a problem is found.

Formal education contexts are comparatively unfamiliar when compared to real-life experiences as they often emphasise abstract, decontextualised knowledge that is often difficult to transfer to real-life situations (Choi and Hannafin, 1995). This knowledge is then inert, and can be recalled in tests, but not readily applied in problem-solving situations encountered in everyday life (Cognition and Technology Group at Vanderbilt, 1990). However, in informal learning contexts, learners can apply knowledge practically to solve everyday problems (Brown *et al.*, 1989). Knowledge and tools can only be fully understood through their regular use, and use of these tools requires learners to change their view of the world (Brown *et al.*, 1989).

✎ **Situated cognition** promotes higher-order thinking (metacognitive) skills in contrast to the mere memorisation of factual information (Choi and Hannafin, 1995). Metacognitive knowledge refers to the awareness of one's cognitive processes (Hill and Hannafin, 1997). Flavell (1979) states that a metacognitive experience is any conscious cognitive experience that pertains to an intellectual enterprise. Wang, Haertel and Walberg (1990) described several key metacognitive tasks as important for learning and understanding. These tasks include self-regulation and self-control strategies, and the use of these strategies to facilitate generalisation. Metacognitive knowledge enables an individual to reflect, evaluate, and steer cognitive activities effectively (Perkins, Simmons and Tishman, 1990). Weak metacognitive skill may limit learners in defining their learning needs and revising their learning strategies (Hill and Hannafin, 1997). Furthermore, metacognitive skills may be impaired by disorientation, frustration, and impatience (Hill and Hannafin, 1997).

### 1.3.3 Cognitive styles

While it may be agreed that presented information needs to be contextualised, and must draw its meaning from the real world, not everyone will gather this contextualised information in the same way. Different people have different cognitive styles, or different ways of thinking and assimilating information. Riding and Cheema (1992) suggest that people may be classified as either one of two cognitive-styles: either the *wholist-analytical dimension* or the *verbaliser-imager dimension* of cognitive style.

The *wholist-analytical dimension* describes the habitual way that an individual processes information and is derived from the work of Witkin and his co-workers (Witkin *et al.*, 1977; Sadler-Smith, 1996). Basically, analytics process information into its component parts, whilst wholists retain a wider view of the topic (Sadler-Smith, 1996a). A further distinction can be made between *verbalisers* and *imagers* (Sadler-Smith, 1996). Verbalisers tend to represent information in memory 'in words', whereas imagers tend to represent information in memory in 'pictorial' form (Riding *et al.*, 1989). These two style-type dimensions may be combined to give four basic cognitive styles.

According to Rieber (1996a) there is a large body of research demonstrating that the way information is represented matters greatly in the learning process. Sadler-Smith and Riding (1992) found that both dimensions of cognitive style appear to affect an individual's learning performance. For example, the *verbaliser-imager dimension* is concerned primarily with the mode of presentation of the information (Sadler-Smith and Riding, 1996) whereas the *wholist-analytical dimension* is concerned primarily with the structure of the information presented (Riding *et al.*, 1989; Riding and Sadler-Smith, 1992). Verbalisers show preferences for information presented in textual form, whereas imagers show preferences for information presented in pictorial or diagrammatic form (Riding and Ashmore, 1980; Riding *et al.*, 1989; Riding and Douglas, 1993). Wholists, on the other hand, may benefit from a hierarchical course structure which makes explicit the course topic in terms of its' component parts, whereas analytics may benefit from a non-hierarchical course structure that gives an overview of the whole topic (Sadler-Smith, 1996b).

One could expect the learning performance of an individual to vary according to the compatibility of the mode and structure of the information being learned with relation to their cognitive style (Sadler-Smith, 1996a). Imagers should benefit from diagrammatic or pictorial presentation of information, and verbalisers should benefit from a predominantly textual presentation of information, with some pictorial and diagrammatic representation as well (Riding and Ashmore, 1980; Riding and Calvey, 1981; Riding *et al.*, 1989; Riding and Douglas, 1993). Wholists should benefit from the inclusion of an agenda showing the structure of the course content, all its' divisions and sub-topics, and analytics should benefit from the inclusion of an agenda giving an overview of the whole and showing relationships between the component parts (Riding and Sadler-Smith, 1992; Riding and Douglas, 1993).

#### **1.3.4 Presentation styles**

Some authors argue that the more senses we use when learning, the better our retention and understanding of information (Amory, 1997) while others suggest that dual processing may confuse the learner by placing too many demands on them (Williams and Snipper, 1990; Fisher, 1998). However, the use of multi-modal processing is a viable technique when used correctly, and is ardently supported by proponents of instructional technology (Amory, 1997). Increasing the sensory input, coupled with interactivity, is argued to integrate more rapidly into the learner's development system and allow for deeper learning (Amory, 1997). Paivio's dual coding theory suggests a model of human cognition divided into two dominant processing systems – verbal (linguistic processing) and non-verbal (visual and other non-verbal phenomenon, like emotional reactions) (Rieber, 1996a). Dual coding theory predicts that the use of words and pictures will activate these processing systems in different ways. Pictures are believed to be the more effective medium as they are more likely to be coded visually and verbally, whereas words are believed to be far less likely to be coded visually.

This theory makes two important assumptions: first, that the verbal and visual codes produce additive effects (Rieber, 1996a). That is, if information is coded both verbally and visually, the chances of retrieval are doubled. Second, words and pictures are thought to activate mental processing in different ways (Rieber, 1996a). Three discernible levels of processing can occur within and between verbal and visual systems, namely representational, associative, and referential processing (Paivio, 1990). Representational processing describes the connection between information coming in from the environment and either the verbal or visual system. Associative processing refers to the activation of either the verbal or visual system, and referential processing refers to the building of connections between the verbal and visual system (Rieber, 1996a).

### **1.3.5 Deductive learning**

Traditional instructional design is concerned mainly with deductive learning (Gagné, 1985), and would normally be characterised by presentation of examples and non-examples of practice to students (Gagné, Briggs and Wager, 1988). In contrast, Bruner (1966) advocates inductive learning based on discovery or personal experience in a domain (Bruner, 1986). This is perhaps a method of learning that is more effective. Through engaged experience in a domain, learners induce, or construct, their own concepts and rules based on their interpretation of the instances encountered. Natural learning does not necessarily flow from a fixed sequence of ideas, and sometimes learners gather information through incidental learning (Rieber, 1996a). Incidental learning could be described as the assimilation and accommodation of information that is not described in the learning objectives, but is realised by the learners in their effort to reach their learning goals. The incidental learning architecture is based on the creation of tasks whose end results are inherently interesting, and which can be used to impart dull information (Reeves and Hedberg, 1998). Students who learn in incidental ways apply this information in a variety of contexts, some of which may be appropriate and constructive to a larger set of learning goals. However, there is always the danger that some of it may actually undermine some learning goals by promoting misconceptions (Rieber, 1996a).

### **1.3.6 Collaborative learning**

A powerful tool in learning is the concept of collaboration. Group interaction is an essential part of learning because of the importance of social discourse in learning. This social discourse amongst groups has the ability to often create and modify beliefs of the individual participants of the group (Choi and Hannafin, 1995). Collaborative learning is important not only because it stimulates learners to interact with their teachers, but also stimulates interaction with their peers (Brailsford *et al.*, 1997). Collaboration is inherent in everyday interaction as people attempt to solve problems by interacting with other people.

In cooperative learning, students learn to negotiate meaning with others and experience shared responsibility for learning. Learning by working in small groups benefits students both instructionally and socially, and modern educational theory supports the concept of group work and the resulting collaboration (Reeves, 1995). Most contemporary science and engineering advances require wide-scale collaboration (Tinker and Thornton, 1992). As we move into the future, it is important that our education system produces young adults who are capable of solving problems, working in collaboration with other people, are capable of accessing and critically processing vast quantities of information and can build on prior experience (Amory, 1997). It is, therefore, important to teach students skills required for collaboration and to convey the message that technical fields are often collaborative (Tinker and Thornton, 1992).

### **1.3.7 Active learning**

In addition, learning environments need to encourage active learning and provide opportunities for students to internalise information (Choi and Hannafin, 1995). A number of features can be used as indicators of active learning, including ownership, access, operation, organisation, ease of use and functionality (Greening, 1995; Amory, 1997). As children, we learn about the world about us through exploration, usually associated with play. Through the process of exploration, learners can take responsibility for their learning, and can therefore construct their own understanding rather than being taught specific knowledge (Winn, 1993). According to Greening (1998), student ownership of the learning tasks should be regarded as the basic principle of the constructivist pedagogy. This author goes on to say that where ownership occurs, active learning and regard for learner's prior constructions will follow naturally (Greening, 1998).

### **1.3.8 Self-regulated learning**

With student ownership comes self-regulated learning. Self-regulated learning exists when individuals assume personal responsibility and control for their own acquisition of knowledge and skill (Rieber, 1996a). Intrinsic motivation is an essential characteristic of self-regulated learning (Rieber, 1996a). The advantages of self-regulated learning are obvious in that learners become more active in the learning process and assume responsibility for the learning process. The implication is that students do not simply participate in a given lesson, but actually help to design it (Rieber, 1996a).

In summary, learning can take place in many ways. For effective learning to take place, knowledge should be uniquely constructed by people through play, exploration and social discourse with others. Learning objectives should be firmly embedded in context, and should, at least in some way, represent every day life situations. Learners should also accept responsibility for their own learning, and be self-motivated to explore

the knowledge domain of a certain topic. They should be intrinsically motivated, and should want to learn. Intrinsic motivation can be promoted by the design of active learning environments that promote incidental as well as deductive learning. Therefore, when educating people, it would be imperative to strive toward a teaching practice that presents knowledge to the users in a contextualised form, and for those learners to take ownership of this knowledge, internalise it, and construct their own view of this knowledge based on their previous life experience.

#### **1.4 Learning models**

The effect of individual differences on the effectiveness of learning is a fundamental issue for teaching (Sadler-Smith, 1996b). One aspect of individual difference that has been widely discussed and investigated is 'learning style' (Sadler-Smith, 1996b).

Various theories have been put forward concerning learning style. For example, Kolb (1976) proposed the Learning Style model describing two bipolar dimensions, namely abstract conceptualisation (AC) versus concrete experience (CE) and reflective observation (RO) versus active experimentation (AE). Research shows that on average, primary school teachers and learners prefer the abstract conceptualisation and active experimentation learning style approaches (Kolb, 1981; Clariana, 1997). Pask (1976) identified two main different types of learners, namely 'operation learners' and 'comprehension learners'. Whilst operation learners were said to concentrate on procedural detail, and were linked with relatively passive learning approaches that focussed primarily on low-level detail, comprehension learners concentrated less on procedural information and displayed a more holistic, active learning strategy. An extreme comprehension learner would therefore gain too general an overview not supported by valid detail and, conversely, an extreme operational learner would overemphasise the detail at the expense of the overall picture (Pask, 1976). Pask also identified 'versatile learners', who were able to combine overview with detail to achieve effective learning.

Ford and Ford (1992) state that two different modes of thinking result in relative success. The first of these is characterised by a relatively passive intake of information, coupled with an attention to low level procedural detail, and was associated with female students (Ford and Ford, 1992). The second was relatively active and concentrated on conceptual overview material, and was associated with males (Ford and Ford, 1992). In contrast, two principle modes of thinking were found to result in failure: those that were characterised by concentration on middle level material whilst asking questions relating to procedural information and those that concentrated on low-level details while asking conceptually-based questions (Ford and Ford, 1992).

Two widely used models of the learning process are Kolb's model of experiential learning (Kolb, 1984), and one of its derivatives, Honey and Mumford's 'learning cycle' (1989). Both these models are based on the Lewinian model of learning (see Kolb, 1984: p. 21) that described four stages in a learning cycle. These stages can be summarised as follows: *Stage 1*: concrete experience; *Stage 2*: observations and reflections on the experience; *Stage 3*: formation of abstract concepts and generalisations based upon the experience and the subsequent reflections; *Stage 4*: testing the implications of the concepts and generalisations in new situations (Sadler-Smith, 1996a).

Honey and Mumford (1989) altered Kolb's approach and classified learners in terms of their strengths and weaknesses for each stage of the cycle. Four contrasting learning styles were identified as 'activists', 'reflectors', 'theorists' or 'pragmatists' (Honey and Mumford, 1989). Activists are learners who immerse themselves in new tasks, and then move on relatively quickly as the excitement fades. Reflectors, on the other hand, were identified as cautious and thoughtful learners that based their decisions and actions on observation and reflection. Theorists were described as learners who had the ability to integrate their observations into logical models based on analysis and objectivity and, finally, learners who liked to implement new ideas immediately and who became frustrated with overemphasis on reflection were termed pragmatists (Honey and Mumford, 1989; Sadler-Smith, 1996a).

## **1.5 Theories of education**

Theories of instruction should ultimately encompass four major spheres (Bruner, 1966). These spheres can be described as including a predisposition toward learning, the structuring of knowledge to facilitate easy concept acquisition by learners, finding the best sequence in which to present material and finally the pacing of rewards or punishments as reinforcement for learning progress (Bruner, 1966). Educational researchers have proposed many theories of instruction. In this study a few prominent theories of education that have affected teaching practice profoundly will be discussed.

### **1.5.1 Maturationism**

Maturationism is based on the premise that the formation of conceptual knowledge is dependent on the learner's developmental stage (Gesell, 1940; Fosnot, 1996). In this paradigm, learners are active meaning-makers interpreting their personal experiences with cognitive structures dependent on these developmental stages (Fosnot, 1996). It follows, then, that learner maturation levels serve as predictors of learner behaviour. This paradigm focuses on stages of growth, and the characteristic behaviours of each stage (Fosnot, 1996). As learners develop, they mature from pre-operational to concrete-operational and finally to formal-operational

stages of their cognitive development (Piaget, 1970). The role of the educator within this paradigm is to provide an environment that appropriately matches the developmental stage of the learner, therefore providing learners with the tools they need to learn. Learner success in this paradigm is assessed in relation to developmental milestones (Fosnot, 1996).

### **1.5.2 Behaviourism**

Skinner (1974) described behaviourism as the philosophy of the science of human behaviour. This paradigm makes the assumption that learners are merely passive and need to be extrinsically motivated to learn (Skinner, 1953). Educators in this paradigm are concerned with the effects of reinforcement, practice and external motivation on learned behaviours (Skinner, 1974; Fosnot, 1996), while learners are seen to simply acquire knowledge by listening to teachers who communicate clearly, or by engaging in experiences with feedback (Fosnot, 1996). Education in this paradigm is reliant on sequenced, well-structured curricula and the provision of extrinsic motivation. As long as clear communication and the appropriate reinforcement is available, learners are expected to progress in a linear and quantitative manner along a clearly described continuum of milestones (Fosnot, 1996). Further, it is assumed that if mastery is achieved at each level along this continuum, then the general overarching concept, defined by the accumulation of skills, has also been taught. Much of the prevalent practice in schools today stems from this behaviourist psychology (Fosnot, 1996). Although behaviourist theory often explains behavioural change well, it offers little in the way of explaining conceptual change.

### **1.5.3 Constructivism**

Constructivism is a theory that often stands in opposition to both behaviourism and maturationism. This paradigm focuses on concept development and deep understanding, rather than behaviours or skills, as the goals of instruction (Bruner, 1960; Fosnot, 1996). Furthermore, this concept development and deep understanding result from learner construction of knowledge (Piaget, 1970). The fundamental principle of constructivism, therefore, is not that knowledge is transmitted directly from one known to another, but is actively constructed by the learners themselves (Piaget, 1970; Driver *et al.*, 1994; Boyle, 1997). Knowledge constructions of this nature come about through interactions with one's environment or culture (Rieber, 1996a). Constructivist theory stems primarily from the field of cognitive science and research centred on the role of representation in learning (Fosnot, 1996). Authors who have influenced this field of study include Jean Piaget, Jerome Bruner, Lev Vygotsky, Howard Gardner and Nelson Goodman amongst others (Fosnot, 1996).

The first great constructivist was Jean Piaget (Piaget, 1970). His work deeply influenced school practice by changing conceptions of learning and teaching (Boyle, 1997). Piaget didn't disagree with all aspects of maturationism or behaviourism, but took exception with the concept of learning being a passive process for the learner. Piaget's life focused on what he termed 'genetic epistemology' (Piaget, 1970). The concept of cognitive structure is central to this theory. Piaget defined four primary cognitive structures (i.e. developmental stages): sensorimotor, preoperations, concrete operations, and formal operations (Piaget, 1978). This model describes cognitive function at differing stages in development, starting with intelligence in the form of motor actions (0-2 years) and slowly working through a process of cognitive development until the final stage, termed the formal operations (12-15 years) (Piaget, 1978). In the formal operations, thinking involves abstractions (Beard, 1969). While the stages of development identified by Piaget are associated with characteristic age spans, they may vary for each individual.

A major theme in the theoretical framework of Bruner was that learning is an active process in which learners construct new ideas or concepts based upon their current or past knowledge (Bruner, 1966). The learner transforms information, forming hypotheses and making decisions, relying on cognitive structures to do so. Cognitive structure provides meaning and organisation to experiences and allows the individual to "go beyond the information given" (Bruner, 1966).

Cognitive structures change through the process that Piaget termed 'equilibration', which consists of two components: assimilation and accommodation (Piaget, 1970, 1978; Rieber, 1996a). Assimilation is the term given to the one's interpretation of their surroundings relative to their existing cognitive structure, whereas accommodation is the term describing the change of the cognitive structure to make sense of the environment (Piaget, 1970). Through interacting with the environment, a child builds mental structures to make sense of its surroundings. The adequacy of that cognitive representation is tested in further interactions and mental structures are transformed in response to feedback received (Boyle, 1997). Therefore, cognitive development consists of constant assimilation and accommodation to make sense of the environment. According to Fosnot (1996), equilibration is not a sequential process of assimilation, then conflict, then accommodation, but rather a dynamic process of progressive equilibria, adaptation and organisation, growth and change.

Piaget's model shows that knowledge and mind cannot be separated because they are part of an open system where one affects the other (Fosnot, 1996). In contrast to the view where development determines the type of learning that can take place, Piaget's model instead suggests that the act of learning is development in itself. (Fosnot, 1996). For Piaget, constructivism means constructing adapted representations of reality (Boyle, 1997).

### *Social interaction*

Whilst Piaget's theory concentrated mostly on the ability of learners to perceive and construct knowledge through interaction with objects, he also acknowledged the importance of socialisation in the process of learning (Driver *et al.*, 1994). To Piaget, socialisation was important for the added viewpoints it would afford learners when discussing concepts (Driver *et al.*, 1994). Lev Vygotsky, on the other hand, was a Russian psychologist who stressed the importance of this socialisation process. In so doing, Vygotsky provided a complementary view to Piaget's approach. He believed that the nature of social interaction and the influence of cultural transmission made possible through these social interactions played a major role in intellectual development (Vygotsky, 1986; Boyle, 1997). It was this interaction between the individual and society, and thus the effect of social interaction, language, and culture on learning that became the focus of Vygotsky's work (Fosnot, 1996).

### *Spontaneous and scientific concepts*

While Piaget considered the process of assimilation to be standard, Vygotsky differentiated between the assimilation of what he called spontaneous and scientific concepts. He defined spontaneous concepts to be the constructions studied by Piaget that resulted from everyday life (Kozulin, 1986; Fosnot, 1996). In other words, these were the concepts that children could develop naturally in the process of construction and tended to pertain to the physical environment. Scientific concepts, conversely, were defined as originating in the classroom, and being more logical and formal abstractions than spontaneous concepts (Fosnot, 1996).

Vygotsky argued that scientific concepts didn't come to the child naturally, but instead had to be substantially developed, a process dependent on the child's existing level of cognitive ability (Vygotsky, 1986). He believed that spontaneous and scientific concepts were processed in different ways. Spontaneous concepts would be subjected to the child's logic before being assimilated and accommodated into the cognitive structure. Scientific concepts, on the other hand, would impose their logic on the child (Vygotsky, 1986; Fosnot, 1996). Learners would only be able to make sense of scientific concepts when enough of a contextually relevant spontaneous concept base existed in the child (Vygotsky, 1986).

Vygotsky also defined a 'zone of proximal development' describing the place where a child's spontaneous concepts meet the "systematicity and logic of adult reasoning" (Kozulin, 1986, p. xxxv). This zone varies from child to child and reflects the ability of the learner to understand the logic of the scientific concept

(Fosnot, 1996). Vygotsky maintained that the most effective learning took place when adults drew children out to a jointly constructed understanding of the subject material (Vygotsky, 1986).

### *Scaffolding*

The process of explanation between teachers and individuals, or even small groups of students, may involve interactions wherein the more competent individuals offer guidance and help to less-informed individuals (Driver *et al.*, 1994). Bruner (1986) referred to this help as “scaffolding”. Scaffolding could be defined as the provision, and timely removal, of extrinsic contextual support (Boyle, 1997), and is not necessary when cognitive structures are well developed, but rather when cognitive structures are unstable or incomplete (Brown and Palincsar, 1989). This support can be used effectively in the design of interactive learning environments, and the need to for this support is highlighted particularly in complex or abstract domains (Boyle, 1997).

Greenfield (1984) identified five benefits of scaffolding: 1. It provides a support, 2. It functions as a tool, 3. It extends the range of the worker, 4. It allows the worker to accomplish a task not otherwise possible, and 5. It is used selectively to aid the worker where needed (Choi and Hannafin, 1995). Scaffolding, therefore narrows the gap between task requirements and skill levels by providing the necessary contextualised support (Greenfield, 1984).

Bruner (1966) suggested a ‘spiral’ learning approach where the simplest and most general ideas were introduced to the learners first, before reintroducing these ideas at higher and higher levels of abstraction at a later time (Bruner, 1966). This approach lays a foundation for the learner, and allows them, at a later stage, to construct new meanings based on this foundation of knowledge.

### *Accommodation*

Disequilibrium facilitates learning (Piaget, 1978; Fosnot, 1996). Rather than avoiding them, errors should be a valuable part of the learning process (Fosnot, 1996), especially during discovery-based or inductive learning (Mayer, 1983, 1989; Rieber, 1996a). Cognitive conflict or puzzlement is essential to learning and is, itself, the stimulus for learning (Savery and Duffy, 1995). For Piaget what is essential for learning is the need for accommodation when current experience cannot be assimilated in existing schema (Piaget, 1978; von Glasersfeld, 1989). Learning environments should be designed to encourage the process whereby learners can reexamine and manipulate all the variables that resulted in an error and consequently reformulate their hypothesis regarding the knowledge domain (Mayer, 1983, 1989).

## **1.6 Technology in education**

Computers have been involved with education, to varying degrees, since the early 1970s. Since then there has been a growing need for the use of computers as tools for the enhancement of education. In the past, however, many unrealistic expectations have been placed on the role of computers in education and ideals have generally not been realised (Waddick, 1994). At the inception computers were used for Computer Aided Instruction (CAI) – a limited application in which the computer dictated learning to the users (Waddick, 1994). More recently, though, computers are being used in conjunction with constructivist learning principles and function as learning tools under the learner's control (Waddick, 1994).

Because technology has had a profound impact on our economy, it has helped shape our culture and has become part of the human environment (Dwyer, 1995). Because of their increasing role in our lives, computers should be incorporated into education and training and, used appropriately, should ultimately aid the learning process (Dwyer, 1995). The immediacy of response offered by computers can offer valuable support for cognitive processes (Dwyer, 1995).

## **1.7 Use of technology in constructivist learning environments**

### **1.7.1 Learning tools**

Constructivism offers great scope for exploiting the opportunities offered by modern technology. Computers are the ideal tools for creating learning environments based on constructivist teaching principles, as they offer a number of features that are central to the constructivist paradigm (Boyle, 1997). A number of these principles, and how computers can facilitate their use, will be discussed in this section.

When dealing with constructivist principles and design, it is important for the technology to have support for non-linear navigation of information and learning experiences (Greening, 1998), and in this way computers offer flexibility (Spiro *et al.*, 1991). The appropriate uses of technology are those that enable active student construction of knowledge, not drill (Tinker and Thornton, 1992). The technology that best supports the construction of knowledge is tool-like, because tools are general, powerful, flexible, and easily used (Tinker and Thornton, 1992).

Even more important than the use of computers as tools, learners should learn to solve problems, make decisions and interact using these tools (Kearsley, 1998). Furthermore, constructivist principles are embraced

most effectively when software tools engage students in authentic tasks and accede ownership of these tasks to the learners (Tinker and Thornton, 1992).

Computers can positively contribute to many aspects of constructivist learning, including collaboration, communication, simplified data acquisition and display and the freeing of short-term memory by allowing access to information stored in databases and by seamlessly performing calculations (Tinker and Thornton, 1992). In addition, because of their wide range of capabilities and tool-like operation, computers eliminate the need for specialized and expensive apparatus (Tinker and Thornton, 1992).

### **1.7.2 Different learning styles**

Despite the fact that every learner brings their own unique life experience and knowledge to the classroom, teaching approaches have traditionally made very little effort to accommodate these learner differences (Reeves, 1995). Computer-based education, on the other hand, can take learner differences into account and can accommodate different learning styles (Reeves, 1995). Computers can also modify their instruction based on the errors made by an individual learner (Burton and Brown, 1982) or recommend appropriate instructional strategies based on learner performance (Tennyson and Buttrey, 1980). Furthermore, computers can aid those that learn more effectively through social discourse because when used in group exercises, computers encourage the expression of varying points of view (Reeves, 1995).

### **1.7.3 Collaboration**

Knowledge is constructed through the process of social negotiation and through the subsequent self-assessment of individual understandings (Savery and Duffy, 1995). Collaboration with others is important because it enables learners to examine their own understandings in the light of alternate views expressed by other members of the group (Savery and Duffy, 1995). Often these alternate views are a source of puzzlement and making sense of the new information would require the learner to accommodate this information into their cognitive structures, thereby enabling further learning (von Glaserfeld, 1989; Savery and Duffy, 1995). Therefore, collaborative groups are a valuable mechanism for enriching and building on a learner's understanding of a particular issue (Savery and Duffy, 1995).

Collaborative group work is an effective learning strategy as it promotes social interaction in the group working together to achieve a unified goal, but supports the reflection of the learner's experiences on an individual level (Collis, 1997). This type of collaboration can be readily enhanced by the use of information technology (Collis, 1997) and it has been shown that learners who participate in this type of strategy

demonstrate higher levels of skill development and self-reported learning than learners taught by conventional means (Alavi, 1994). In collaborative groups, dialogue is encouraged not only between learners and their teachers, but also between learners themselves (Brailsford *et al.*, 1997).

#### **1.7.4 Cognitive support**

Constructivist learning environments tend to promote inductive learning. By inducing knowledge, learners make each "truth" they discover their own through the process of reinvention (Piaget, 1970). This approach leads to deeper levels of understanding and also intrinsically motivates students to persist in their task (Rieber, 1996a). However, novices often need structure or guidance that purely inductive experiences do not provide (Jonassen, 1986). Inductive activities also require an attitude of playfulness and exploration which adults may resist (Rieber, 1996a).

Cognitive support for a learner in a constructivist environment is of great importance. In situated learning environments, learners are provided with ongoing, interactive, and continuous support in their personal constructions of meaning about the world they experience (Choi and Hannafin, 1995). This affords learners opportunities for the internalisation of information and promotes metacognitive skill development, self-regulation and self-assessing abilities (Choi and Hannafin, 1995). Without the appropriate 'scaffolding' learners may soon become disinterested, bored or frustrated with a learning environment (Rieber, 1996a). Challenge is a form of scaffolding that provides intrinsic motivation, too little of which would make an environment uninteresting and boring, and too much of which would cause frustration and would ultimately become counterproductive (Brandt, Farmer, & Buckmaster, 1993). Scaffolding essentially closes the gap between the task requirements of the learning environment and the learner's skill level (Greenfield, 1984). Therefore, it is important that tasks be designed to be optimally challenging in that they are neither too easy nor too difficult. Perhaps most importantly, tasks should make learners feel that they are competent and capable of performing tasks perceived as relevant (Malone, 1981a; Rieber, 1996a).

#### **1.7.5 Electronic games**

Ironically, the domain in which computers really can deliver powerful learning experiences is one that education largely ignores: games. Computer games provide elements of fun and challenge and encourage learners to exercise their problem-solving and decision-making skills (Kearsley, 1998). Furthermore, because of their flexible nature, games can be applied to almost any knowledge domain (Kearsley, 1998).

McKee (1992) and Billen (1993) argue that games affect cognitive functions and motivation, and that they remove the player from the "real world". However, Neal (1990) stated that games could encourage goal formation and competition. Furthermore, games can be powerful tools because they appear to inherently motivate learners, enticing their curiosity (Thomas and Macredie, 1994) with challenges and elements of fantasy (Malone, 1981a, 1981b). Fantasy is important in that it provides learners with a meaningful context for learning and the high level of fascination that often results, serves as a source of intrinsic motivation for learners (Rieber, 1996a). Numerous authors agree that this intrinsic motivation is a direct result of the novelty and complexity of games (Malone, 1984; Malone and Lepper, 1987; Rivers, 1990).

Electronic games are part of the popular culture of a great number of children and it is argued that education needs to be responsive to this culture (Boyle, 1997). Games offer a powerful format for learning because they are capable of interesting the learner and intrinsically motivating them to learn (Boyle, 1997). By providing complex, ill-defined, and authentic tasks in an appropriate context, situated learning environments induce inferential reasoning, monitoring and regulation of problem-solving, and utilisation of metacognitive skills (Winn, 1993).

### **1.7.6 Microworlds**

Papert developed an idea that is highly relevant to interactive multimedia learning environment design: 'Microworlds'. A microworld is a small but complete subset of reality where one can go to learn about a specific domain through personal discovery and exploration (Papert, 1981; Dede, 1987). At first a microworld could be developed with Logo to let the child actively explore certain abstract concepts. Today, multimedia provides the basis for much more sophisticated microworlds than can be created in Logo (Boyle, 1997). Papert (1980) suggested that microworlds should fulfil 4 criteria: they should be simple, general, useful and compatible. Papert argued that microworlds provided a better basis for learning than did abstract descriptions in textbooks (Papert, 1981). The concept of microworlds provides a potentially very powerful technique for constructing sophisticated interactive learning environments (Boyle, 1997).

Microworlds can be designed to give learners exploratory experiences within a carefully controlled range of concepts and principles (Rieber, 1996a). Carefully designed microworlds should expect and encourage incidental learning to occur within these design parameters (Rieber, 1996a). Background information increases the acquisition of domain knowledge within the microworld (Leutner, 1993). An essential part of the microworld approach is engaging the learner's imagination, and once this has been achieved, learners can acquire skills and knowledge through their experiences in the simulated environment (Boyle, 1998). Use of gaming structures is a powerful method for promoting learner engagement with knowledge domains. These

structures may be based on arcade games or adventure games. There is a clear continuum from simulations to games, with the ultimate expression of simulation being full virtual reality. Virtual reality is potentially one of the most powerful media applications for educational systems (Boyle, 1998).

### **1.8 Design of constructivist learning environments**

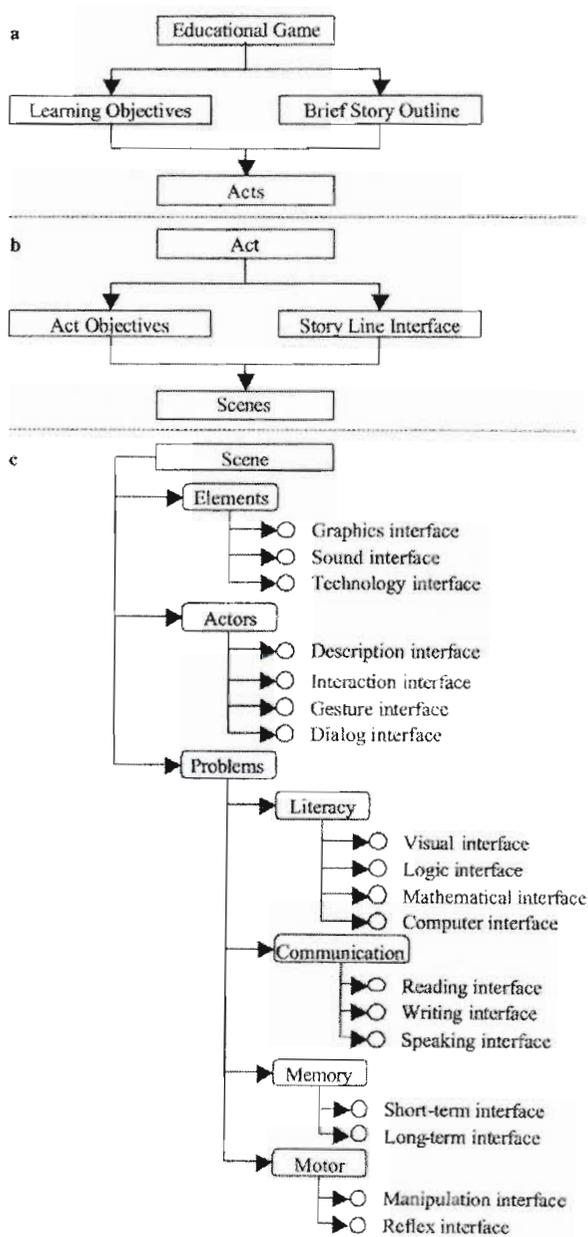
Rieber (1996) puts forward some design considerations for computer-based microworlds: (1) Provide a meaningful learning context that supports intrinsically motivating and self-regulated learning, (2) Establish a pattern whereby the learner goes from the "known to unknown", (3) Provide a balance between deductive and inductive learning, (4) Emphasise the usefulness of errors, and (5) Anticipate and nurture incidental learning. According to Boyle (1997), there are three areas of knowledge and skill required for the effective design and delivery of multimedia learning environments. These three areas involve conceptual design, presentation design and project management (Boyle, 1997).

An inherent fault with educational computer games lies not in the suitability of the technology for the purpose, but rather in the principles on which the game is designed. Designers are faced with the seemingly dichotomous considerations of either making the game exciting or making it educational. Given a dull and often uninspiring track record for educational simulations, this perceived dichotomy is not surprising. In theory, with the correct framework and design principles, games that are both exciting and contain educational merit can be produced. One such framework, the Game Achievement Model (Figure 1.2), has been proposed by Amory (2002). This model was followed throughout the duration of this study and, in addition to using the model's design constructs, the model itself was evaluated for its effectiveness and suitability as a tool.

The Game Achievement Model (GAM) provides a framework for game designers to link learning theory to game design (Amory and Seagram, 2003). This model does not clearly define how to design and build educational games (Amory and Seagram, 2003), but rather provides a tool to ensure that the creation of a game is soundly based on educational principles.

Central to the development of any educational game is the definition of the learning objectives for that game (Amory, 2001; Amory and Seagram, 2003). Realisation of these learning objectives is paramount for the success of the game. Intrinsic motivation is the tool whereby games have the power to succeed over and above other forms of learning (Rieber, 1996a). A compelling storyline in any game provides interest and motivation on the part of the learner (Malone, 1981a). Essentially, what the GAM seeks to do is marry a good

story to sound educational objectives, thus minimising the risk of making a game either too instructional or too story-like with no real educational benefits (Amory and Seagram, 2003).



**Figure 1.2** The Game Achievement Model (GAM) taken from Amory and Seagram (2003). The model has various levels for (a) determining the learning objectives and a brief storyline, (b) for refining and building on the storyline as well as the definition of Acts within the story and (c) designing each scene using elements, actors and problems.

Learning objectives are realised through the inclusion of problems into the game. By solving these problems, learners should be encouraged to question the system, internalise and construct their own knowledge about the subject material.

Games, therefore, consist of three inter-linked gears: the story, the problems and the graphical realisation of the story and problems (Amory and Seagram, 2003).

Briefly, there are three priorities described in the GAM. The first priority is to describe the learning objectives for the game and to decide on a basic storyline for the game. The second priority is to break the story down into various acts. As in traditional theatre, each act needs to achieve specific objectives, tell a part of the story and can consist of one or more scenes (Amory and Seagram, 2003). The learning objectives for each act must be realised in the scenes that make up that act. Accordingly, the third priority of the model is to define these scenes and how they will achieve the learning objectives for the act.

Each scene is made up of a number of facets, namely *elements*, *actors* and *problems*. Each of these facets has a set of interfaces that need to be taken into consideration when designing a scene. The GAM helps the designer to think of these different interfaces and include them into the scene to realise the best way to achieve the act learning objectives (see Amory and Seagram, 2003).

### **1.9 Evaluating the interactive learning environment design process**

Evaluation of interactive learning systems tends to be severely under utilised or non-comprehensive in nature, with the majority of evaluations that are conducted being targeted at delivery systems themselves rather than instructional design aspects of the systems being evaluated (Reeves and Hedberg, 2003). This lack in formative evaluation poses a major problem for the field of interactive learning system design in that advancement in any field is almost impossible if the effectiveness of existing techniques and models are not assessed, their strengths accentuated and their weaknesses improved. Reeves and Hedberg (2003) suggest that the emergence of new paradigms in interactive learning circles is not likely because evaluation in this field has been traditionally so inconsistent and rare that viable design practices have seldom been given time to become established and influence the later work of designers in that field. Evaluation of the process employed for the design of educational games is therefore imperative.

Accordingly, one of the primary interests of this study was the evaluation of the model used in the design of the situated learning environment detailed in this study. The benefits and disadvantages of this model, once elucidated, would set the stage for future improvements and advancement of the science.

Throughout the evaluation of the design process, the Eclectic-Mixed Methods-Pragmatic Paradigm, a mixed mode of inquiry, was adopted. This inquiry paradigm subscribes to the use of multiple evaluation techniques to get a more rounded understanding of the complex nature of interactive learning environments, whilst maintaining a practical approach to problem solving (Reeves and Hedberg, 2003). This approach, therefore, acknowledges that the often complex social aspects of interactive learning system design cannot merely be quantified, and qualitative and quantitative evaluation methods are utilised in unison for a more comprehensive analysis. The evaluation of the game design process was one of reflection and analysis.

### **1.10 GammaKhozi – a constructivist learning environment**

Using the GAM as a theoretical framework against which to work, a portal for the constructivist 3D virtual world adventure game, GammaKhozi, currently being developed by the Virtual Learning Spaces Project (VLSP) at the University of Natal, Durban, was designed. The aim of the VLSP team is to create an immersive and interactive 3D adventure game that allows learners to explore different knowledge domains, each centered around an aspect of South African heritage or culture. By playing the game and interacting with other learners online, it is hoped that this learner cross-interaction will foster a spirit of community amongst learners and that this spirit will lead to a deeper understanding of what it means to be part of a true democracy. It is hoped that, by being part of the online community, learners will interact with one another, promoting cross-cultural information exchange. Learners should also realize the need to tolerate others, some of whom will potentially have different views and opinions on critical issues. If we are to live in a true democracy, we must learn to respect others, even if we don't share the same beliefs. In a democracy, compromises must be made by both parties and all members should reasonably tolerate one another.

Within this 3D Virtual Learning Space, two main areas exist, each suited for different purposes. The first area, where much of the learner interaction and information exchange will occur, is called the Inner City. It is in this Inner City where the learners "live" and essentially learn about being part of a democratic society.

The second area, comprising a number of different microworlds collectively referred to as the "portals" and situated external to the Inner City, is where learners interact with specific knowledge domains. Whilst inside any portal, the learner's main goal is to explore the surroundings, assimilate, accommodate and reflect upon the information or principles presented to them in their interaction with the environment.

By acquiring and accommodating the information presented in the portals, learners are rendered capable of solving an ultimate mystery or puzzle inherent in that portal. For example, if something untoward is suspected of happening in the portal, by gaining as much knowledge from their interaction with the portal resources and

puzzles, the learners equip themselves with the information necessary to solve the mystery and earn credit and power as recognition of this achievement.

In the first phase of portal development planned for the game design, an allocation for six independent portals was made. One of the portals entitled “In the service of humanity. Disease, epidemics, cures and failures”, was the portal with which this project concerned itself.

### **1.11 The focus of the current study**

The current study revolved around the incorporation of valuable life knowledge concerning four major sub-Saharan diseases into a constructivist learning environment or, more specifically, a 3D virtual-reality adventure game. The focus of this particular study was the research surrounding the diseases, the definition of the learning objectives and the design and development of the game storyline, game puzzles and game resources inherent in a microworld portal.

One major aim of this portal was to provide a contextualised learning environment that would equip learners with knowledge, based on the biological evidence presented in the game, giving them the informed capacity to dispel any misinformation concerning the pathology and spread of four major diseases.

This microworld would attempt to provide the necessary resources and scaffolding for learners to have successfully and accurately constructed their own knowledge concerning these topics. Intrinsic motivation for the game would be provided by a story-line that would compel learners to progress to the successful completion of the game. To be successful in this quest, the learner would have to first acquire morphological knowledge about the various diseases, their mechanisms of transmission and infection, and cures or vaccines, before then being able to solve the ultimate puzzle of the microworld. Once the mystery had been solved, the game would be complete, and the learner would be credited with the necessary points and power to return to the “inner city” and commence on another microworld adventure. After playing the game, the student should have gained knowledge on the causative organisms, transmission modes and some of the biology behind HIV, malaria, tuberculosis and cancer, as well as the basic distinction between how a virus and bacteria function, and what characteristics make them different.

A second, and perhaps more important, aim was that of assessing the effectiveness of the game design process that was followed. This assessment reflected on the relative success of the game design process and had the ability to highlight design flaws and design strengths in the model employed in the game design. The

elucidation of potential flaws, strengths or areas in which the model was not comprehensive enough, could serve to ultimately better the game design process.

The study was subdivided into five main sections: (1) The choice of diseases upon which the portal would be based. (2) The definition of learning objectives for the portal, (2) the design and testing of the storyline for the portal, (3) the technical aspects of the 3D game design process as well as the design of puzzles for inclusion into the microworld, (4) the evaluation of the model used in designing the environment and the storyline, and (5) the testing of the learning environment and the models for puzzle design.

Chapter two focuses on the four diseases central to the portal, namely HIV/AIDS, tuberculosis, malaria and cancer, and the justification for these diseases having been chosen as important to the portal. This chapter describes the process through which the gaps in knowledge in the target learner population were elucidated and, consequently, how the learning objectives of this portal were decided.

Chapter three describes the process through which the storyline was negotiated and how goals set in this task were met. The effectiveness of the GAM as a theoretical framework for the design of non-linear storylines was evaluated and will be discussed here. In order to gauge the acceptability of the storyline to the future learners, their opinion on this storyline was elicited. Analysis of this qualitative data was carried out and the results are discussed here.

Chapter four explores the technical aspects of the 3D game design and outlines the approach that was used in the design of the various game locations and puzzles. Puzzles that have been created for this microworld are described. The interface, mechanism and educational importance of each of these puzzles will be dealt with in detail. This chapter will show how the knowledge concerning the selected diseases was incorporated into the educational puzzles for the portal, and how a model to facilitate this process was designed.

Chapter five examines the user testing methodology and discusses the results from the testing. Based on observations and empirical data, a more comprehensive model for the design of educational puzzles is proposed.

Finally, chapter six provides a discussion summarising the process undertaken in this study, as well as the advantages and disadvantages of the structural framework that was followed in this design. Shortcomings in the Game Achievement Model are discussed and further models are recommended for use in future puzzle design efforts.

## CHAPTER 2

### DEFINITION OF THE LEARNING OBJECTIVES

#### 2.1 Introduction

Substantial evidence exists that shows the positive effect that education has on young people's reproductive lives (World Bank, 2002). For adolescents, education has proven to provide protection against sexually transmitted diseases, for example Human Immunodeficiency Virus (HIV) (World Bank, 1999). An investment in sex education reduces poverty, improves gender equality, reduces infant and child mortality, improves maternal health and lowers the prevalence of disease (World Bank, 2002). A basic education has a general preventative impact in that it can equip adolescents to make decisions concerning their own lives, facilitate long-term behavioural change, and give them an opportunity for economic independence (World Bank, 2002).

Despite current education policies, knowledge of sexually risky behaviour, and the associated health risks, is not widespread (UNICEF *et al.*, 2002). For example, recent studies from across the world indicate that the vast majority of young people are not aware of how HIV/AIDS is transmitted, or how to protect themselves from this disease (UNICEF *et al.*, 2002). Kirby (1992) states that AIDS educational programs were not likely to reduce risky sexual behaviour unless they did substantially more than just increase knowledge. Schoub (1999) levies the criticism that whilst education itself has often resulted in a greater degree of awareness in African populations, it has often failed to instigate much needed modifications in practices and behaviour.

In this chapter, an historical account of several diseases prevalent in South Africa will be given. A review of this literature will highlight possible health risks posed by these diseases and their often far-reaching effects on South African society. Existing levels of knowledge, as determined by survey data, will be ascertained from the literature and the areas of little known knowledge noted.

Levels of existing learner knowledge concerning these diseases will be ascertained through the use of a questionnaire survey distributed to learners at the University of Natal, Durban. The results of this survey will be given and the implications thereof shall be discussed.

Finally the learning objectives for the portal will be defined to address the gaps in the existing knowledge in the learner population.

### 2.1.1 Encouraging learning versus information dissemination

It is a well known saying that knowledge is power – the more knowledge you have, the more informed decisions and choices you can consciously make. Consequently, the role of education in addressing a pandemic of any description is possibly one of the most important aspects of that address. However, with increasing incidence of HIV infection, malaria, tuberculosis (TB) and cancer cases each year, both globally and locally, it would be easy to assume that the educational initiatives that have been designed to curb these increases have had a limited effect. Countless papers have stressed that the respondents of their studies had most of the answers concerning their field of enquiry, but few of them related that information to their personal lives (Carballo and Kenya., 1994; Tuanyane and Hirschowitz, 1995; Richter, 1996). Perhaps the preventative information has been conveyed in a manner too detached from reality, too decontextualised, to be seen as applicable in the real world. What is needed is a different way of educating the youth of South Africa about major health risks.

The use of computers in health risk education may fulfill these criteria. Multimedia is one of the most powerful tools available to educationists because it can make use of virtual environments in which learners can adopt a persona and explore a knowledge domain at their own pace (Boyle, 1997). Presentation of health risk knowledge in a situated, informal constructivist learning environment might promote a more in-depth understanding of the knowledge domain under exploration, allowing learners to internalize information, accommodate this information in their world view, and therefore construct their own view of the material being presented.

What this portal aims to achieve is an understanding, in learners, of the biology behind the causative organisms of some of the major South African diseases. The concept of a biological entity behind any particular disease allows learners to reject misinformation based on myth about the spread of these diseases that exist in various sectors of our society. For example, the myth that HIV/AIDS is cured by having sexual intercourse with a young virgin (UNICEF *et al.*, 2002) would be dispelled if learners were aware how the HI virus actually spread. Based on a basic level of biological understanding of the causative organisms of these diseases the portal will, using a constructivist learning environment, attempt to make explicit some of the lesser known areas of knowledge concerning these diseases, with particular reference to the biology, structure and transmission of these biological agents.

## 2.2 Choice of diseases for inclusion in the portal

Infectious diseases are the leading killer of young people in developing countries (World Health Organisation, 2000). Furthermore, these infectious diseases can be responsible for up to half of all mortality in developing countries (World Health Organisation, 2000). The poorest people in these countries bare the brunt of disease as they have little, or no access to drugs necessary for prevention or cure. Approximately half of infectious disease mortality can be attributed to just three diseases – HIV/AIDS, tuberculosis and malaria (World Health Organisation, 2000). These three diseases cause over 300 million illnesses and more than 5 million deaths each year. None of these diseases has an effective vaccine to prevent infection in children and adults (World Health Organisation, 2000).

Cancer, too, is on the rise globally, with a 37 % increase in cancer cases worldwide between 1975 and 1990 (Parkin, Pisani and Ferlay, 1999). In South Africa alone, 149 815 new cases of cancer were reported between 1993 and 1995, averaging 49 939 cases per year (Sitas, Madhoo and Wessie, 1998). Cancer affects many individuals in South Africa and, if not treated appropriately, many of these cancer forms can be fatal.

Consequently, the four diseases focused on in this study, due to their increasing occurrence amongst the population of South Africa, were HIV/AIDS, tuberculosis, malaria and cancer.

### 2.2.1 HIV/AIDS

It was in 1981 that health-care workers in the United States recognised an increase in the incidence of certain rare diseases, such as Kaposi's Sarcoma and *Pneumocystis carinii pneumonia* (Campbell, 1993; Hooper, 2000). Manifestations of these diseases are usually rare in that they only occur in severely immunosuppressed individuals (Campbell, 1993). In other words, the human immune system is normally capable of halting the development of these diseases without the need for external intervention. The increased occurrence of these diseases resulted in the recognition of an immune system disorder named Acquired Immunodeficiency Syndrome (AIDS). By 1983, virologists working in the United States and France had identified a causative agent – a virus now known as the Human Immunodeficiency Virus, or HIV (Campbell, 1993). HIV probably arose by evolution from a simian virus present in wild monkeys in central Africa and may have caused unrecognised cases of AIDS in that region for many years (Campbell, 1993; Janse van Rensburg, 2000).

Eighty percent of HIV-positive women live in Africa, and the number of women of childbearing age infected by HIV is higher in Africa than anywhere else in the world (Lawson, 1999). An estimated 11.8 million young

people aged 15 to 24 years worldwide are living with HIV/AIDS and each day, nearly 6000 people (15 to 24 years) become infected with HIV (UNICEF *et al.*, 2002).

In South Africa, the epidemic has escalated disproportionately in recent years. The routine surveillance data obtained by the Department of Health has shown that among pregnant women attending public health clinics for ante-natal care, the prevalence of HIV infection has increased from 0.7 % in 1990 to 24.6 % in 2001 (Department of Health, 2002). It was also estimated that by 2001 approximately 4.74 million people in South Africa between 15- 49 years of age had become infected with the HI virus, and this was an increase of 740 000 HIV infections since the year 2000 (Dorrington *et al.*, 2002).

A possible reason for this marked increase in HIV infection rates is the apparent unwillingness of the younger generation to change their risky sexual behaviour (Richter, 1996). Knowledge, Attitude, Behaviour and Practice (KABP) surveys conducted on sub-groups in some parts of sub-Saharan Africa indicate that although 75 % of the people surveyed knew that AIDS was a sexually transmitted disease there was little evidence of change in behaviour (Carballo and Kenya, 1994). Tuanyane and Hirschowitz (1995) reported that proportionally fewer black respondents (66 %) believed that AIDS was spreading rapidly through South Africa when compared with coloureds (87 %), Indians (92 %) and whites (95 %). Furthermore, it was shown that respondents from all race categories believed that AIDS was spreading, but not through their own particular communities (Tuanyane and Hirschowitz, 1995). Not surprisingly, then, only between half and two-thirds of respondents across all race groups were prepared to either request or administer the use of a condom during causal sexual encounters (Tuanyane and Hirschowitz, 1995). Richter (1996) stated that the majority of young people saw the need for sexual protection in relationships with regular partners, yet their behaviour was not consistent with this knowledge because they all shared a low level of perceived personal risk for sexually transmitted diseases, including HIV/AIDS.

In 1998, the Department of Health acknowledged that there was a high level of awareness (as much as 95%) of HIV/AIDS amongst teenage women in South Africa (Department of Health, 1999), but whilst this majority had heard about HIV/AIDS, many did not know how HIV was spread and did not believe themselves to be at risk (UNICEF *et al.*, 2002).

A possible reason for this perception of low personal risk might be the lack of knowledge many people exhibit when it comes to the actual mechanism of HIV transmission. A national health survey conducted in South Africa showed that while almost all the respondents had heard about AIDS, a large proportion answered incorrectly when asked specific questions about the transmission mechanisms of HIV (Taunyane and Hirschowitz, 1995). Just under 50 % of the respondents thought that HIV could be transmitted through a

mosquito bite, 25 % percent thought HIV could be transmitted through kissing and hugging, and approximately 20 % thought that using public toilets was a mode of transmission (Taunyane and Hirschowitz, 1995). In a study conducted by the Medical Research Council of South Africa, only 44 % of respondents spontaneously linked HIV to AIDS, and only 42 % indicated their knowledge that HIV can be transmitted in the blood (Richter, 1996). There is a clear need for more programs that deal with the mechanisms of transmission in HIV/AIDS, particularly amongst the less educated and rural populations (Taunyane and Hirschowitz, 1995).

### 2.2.2 Tuberculosis

Tuberculosis is widely distributed in Africa and is often linked to HIV infection. HIV infection serves to weaken the immune system which increases the risk factor for developing tuberculosis (TB)(Pio and Chaulet, 1998). An estimated 10.7 million persons in Africa and Asia have dual infection with HIV and *Mycobacterium tuberculosis* (Satcher, 1999), and these people are 800 times more likely to develop active tuberculosis disease (Center for Disease Control and Prevention, 2002).

Tuberculosis is caused by a hardy bacterium, *M. tuberculosis*, which can survive, at least temporarily, almost anywhere (Metcalf, 1991). The main mode of tuberculosis transmission is almost entirely by droplet infection from a person infected with pulmonary tuberculosis that is coughing and producing sputum contaminated with *M. tuberculosis* (Strebel and Seager, 1991). Inhalation of this aerosolised sputum results in tuberculosis infection (Center for Disease Control and Prevention, 2002). Not everyone infected with TB bacteria becomes sick, meaning infected persons can either have latent TB infection or develop active TB disease, both of which are treatable and curable (Center for Disease Control and Prevention, 2002).

About 9 million new cases of TB occur worldwide each year. Including people who are also infected with HIV/AIDS, approximately two million patients die from TB annually (World Health Organisation, 2002). The global caseload is rising, driven up-wards partly by the sub-Saharan Africa spread of HIV/AIDS (World Health Organisation, 2002). Four of the countries with the highest global tuberculosis incidence rates are in the Southern Africa Development Community (SADC) region, and clearly South Africa is one of these four countries (Department of Health, 1997), emphasizing the importance of educating citizens of this country about tuberculosis.

In 1997, it was estimated that South Africa had the second-highest TB/HIV co-infection rate, approximately five times higher than the global TB fatality average (Department of Health, 1997). This is particularly worrisome as TB in South Africa affects mostly the economically active group, with 86.6% of reported TB

patients falling in the age group of 20-59 years (Kironde, 2000). Unlike HIV/AIDS where the highest rates of new infection occur in younger people due to risky sexual behaviour, TB can be transmitted to people across all age groups indiscriminately. In their technical report, the Medical Research Council (2001) named tuberculosis as the third largest cause of death due to disease in men, irrespective of wealth. Furthermore, TB was the third largest killer in poor women, and the fourth largest in rich women in South Africa (Bradshaw and Laubscher, 2002). Pulmonary tuberculosis, which manifests in the lungs, is the most common non-occupational lung disease in South African industry (Lalloo and Mets, 1991).

In similarity with AIDS, part of the reason TB has had such a drastic impact in South Africa can be attributed to because of widespread ignorance or misinformation concerning the disease. Many people are not aware that TB is curable and they don't understand that those infected with the TB bacillus are not contagious until they develop active TB (World Health Organisation, 1998). The general public are also largely unaware that TB sufferers can ultimately lead healthy, productive lives following treatment. Cultural factors and spiritual beliefs also encourage the propagation of misconceptions regarding TB (Dube, 1995). For example, the results of a study conducted in Macambibi, a rural area in Northern KwaZulu-Natal, involving seven people with active TB disease, showed that four of these people had no knowledge of TB and associated the disease with heart disease and asthma, whilst the other three participants believed that they were bewitched with the disease (Dube, 1995).

### 2.2.3 Malaria

Malaria is by far the world's most important tropical parasitic disease, and kills more people than any other communicable disease after tuberculosis (World Health Organisation *et al.*, 2002a). Malaria is caused by a plasmodium parasite (Campbell, 1993), of which there are four that can infect humans: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae* (Centers for Disease Control and Prevention, 2000). The *Plasmodium* parasite has a complex life-cycle, involving asexual stages in humans and sexual stages in the *Anopheles* mosquito (Campbell, 1993), the vector for transmission. Because malaria is transmitted by the *Anopheles* mosquito, the incidence of malaria is mostly contained in low-lying areas with high rainfall, high temperatures and high humidity levels (Sharp *et al.*, 1984). These are the areas where the mosquitoes can breed most successfully. Consequently, malaria is a public health problem today in more than ninety countries, inhabited by approximately 40 % of the world's population (World Health Organisation *et al.*, 2002b).

Worldwide prevalence of the disease is estimated to be in the order of 300-500 million clinical cases each year, more than 90% of which occur in sub-Saharan Africa (World Health Organisation *et al.*, 2002b).

Worldwide mortality due to malaria is estimated to be over 1 million deaths each year, with the vast majority of these deaths occurring among young children in Africa, especially in remote rural areas with poor access to health services. Other groups at a high risk of contracting malaria are pregnant women, non-immune travellers, refugees, displaced persons and labourers entering endemic areas (World Health Organisation *et al.*, 2002b).

Malaria transmission is distinctly seasonal in South Africa with notifications generally increasing from November onwards (Sharp *et al.*, 1988) until June. Malaria control has been instituted in South Africa from 1940 to date, which initially controlled the spread of malaria quite effectively (Sharp *et al.*, 2000). However, since the mid-1980s, when the number of malaria cases was approximately 3000 cases per year, there has been an exponential increase in the number of malaria cases, with the 1999/2000 season wielding just under 40 000 cases (Sharp *et al.*, 2000). The exact cause of this increase in malaria incidence is difficult to pinpoint, but it is thought that the development of resistance to anti-malarial drugs and the re-emergence of a second highly-efficient vector, *Anopheles funestus*, have definitely played a major role (Sharp *et al.*, 2000; World Health Organisation, 2002b). In addition, the increasing resistance of the *Anopheles* mosquito to insecticides and the increasing incidence of HIV/AIDS in the country are also thought to be partially responsible for this increase (Colvin and Sharp, 2001). Mortality rates caused by prevalent diseases, such as malaria, have doubled and tripled because of AIDS (World Health Organisation, 2002b).

Knowledge about malaria is markedly low among affected populations, with a recent survey in Ghana showing, for example, that half the respondents did not know that mosquitoes transmit malaria (World Health Organisation, 2000). In a study conducted in India, it was reported that 8 % of the respondents reported the symptoms of malaria correctly, but 98 % percent of these respondents didn't really know *what* caused malaria (Singh *et al.*, 1997). Furthermore, the results of a study conducted in Northern KwaZulu-Natal, South Africa, showed that only 77 % of natural healers in the area knew that malaria was a contractable disease, with the remaining 22 % attributing malaria to witchcraft or spiritual causes (Dladla, 2000).

#### **2.2.4 Cancer**

Cancer is the name given to more than 100 different types of malignant tumors (National Institutes of Health and National Cancer Institute, 1999; Department of Health, 2001; World Health Organisation, 2002c). It is characterised by uncontrolled cell growth and by the ability of tumor cells to invade neighbouring tissues and spread to other areas of the body (Campbell, 1993; Ward, 1995). Cancer cells differ from normal cells in a variety of ways, including their behavior, biochemistry, genetics, and microscopic appearance (Ward, 1995). Causes of cancer fall into three main categories: chemicals, viruses and irradiation (Ward, 1995).

Chemicals that can cause cancer are referred to as carcinogenic, and are extremely varied in their occurrence (World Cancer Research Fund (WCRF) and the American Institute for Cancer Research (AICR), 1997). Carcinogenic chemicals include substances such as tobacco and asbestos to name a few, and these chemicals are thought to cause approximately one third of human cancers (Ward, 1995; Ames and Gold, 1997). Diet is thought to impact on cancer by causing as much as 30 – 50 % of cancers worldwide (Ward, 1995). High-energy diets coupled with low exercise, and often resultant obesity, have been linked to cancer in humans (WCRF and AICR, 1997). Irradiation plays a smaller role and is thought to cause only 1 – 5 % percent of cancers worldwide (Ward, 1995). Irradiation can include x-ray radiation and ultraviolet light found in normal sun rays (WCRF and AICR, 1997).

Certain viruses are thought to account for 10 – 15 % of cancers worldwide (Ward, 1995), although viruses do not necessarily cause cancer independently. Research has been conducted on tumour viruses that include members of the retrovirus, papovirus, adenovirus and herpesvirus groups (Campbell, 1993). One member of the herpesvirus group, Human Herpes Virus 8 (HHV8), or Kaposi's-sarcoma-associated herpesvirus (KSHP) as it is sometimes called, has recently been linked to Kaposi's sarcoma, traditionally one of the most visible characteristics of the AIDS condition (Ward, 1995; Bourboulia, 1998; Sitas *et al.*, 1999).

Globally, cancer statistics are rising. In 1996 the World Health Report stated that more than 10 million people were diagnosed with cancer and at least 6 million people who had been suffering from cancer died during that year (World Health Organisation, 1997). Furthermore, the World Health Organization (1997) has estimated these figures will double by the year 2020 with a total of 20 million new cases and 12 million deaths from cancer alone. Although cancer has often been regarded principally as a problem of the developed world, more than half of all cancers occur in developing countries (World Health Organisation, 2002c). Cancer is the second most common cause of death in developed countries, and epidemiological evidence suggests the start of a similar trend in developing countries (World Health Organisation, 2002c). Currently, though, cancer accounts for one-tenth of all deaths in developing countries (World Health Organisation, 1997).

In South Africa, an average of just less than 50 000 new cancer cases get reported every year (Sitas, Madhoo and Wessie, 1998). Furthermore, the minimal lifetime risk of contracting cancer in South Africa was calculated at 1 in 6 in males and 1 in 7 in females (Sitas *et al.*, 1998). Currently, the rate of cancer incidence is 238 cases per 100 000 population in South Africa (Department of Health, 2001). Whilst some authors are quick to describe cancer as an international crisis on the rise, others are less convinced, saying that cancer is only marginally increasing in society and, even then, this is because of increased life expectancy (Ames and Gold, 1997). Some of the principal factors contributing to the increase in cancer incidence are an increased

lifespan, an overall decrease in deaths from communicable diseases and the rising incidence of certain forms of cancer such as lung cancer which results from tobacco use (World Health Organisation, 2002).

Because cancer does not bear the “infectious diseases” label, educating people about cancer is perhaps not given as high a priority as other more virulent, contagious or quick acting diseases such as HIV/AIDS, TB and malaria. However, whilst cancer may not be contagious, there are certain facts concerning cancer that would enable people to alter their behaviour and limit their risk of developing cancer. Most cancers, when caught at an early stage, are operable and survival rates are good. However, if cancer is allowed to run its course unchecked, the consequences for the affected individual are severe, often resulting in mortality. The most important factor influencing survival rate is the stage of the cancer at the time of treatment (Sukardja and Asmino, 1983). Cancer risk factors are highest amongst the population group with the least education (World Health Organisation, 2002c). The most effective public health approach to cancer is one that empowers individuals with the knowledge needed to minimize their risk factors concerning cancer (World Health Organisation, 2002c).

### **2.2.5 Diseases summary**

On the basis of the misconceptions and prevalence rates of HIV/AIDS, tuberculosis, malaria and cancer, the major objective for this portal was to create a situated learning environment in which learners could explore aspects of the biology concerning these diseases. The inclusion of appropriate puzzles, grounded in constructivist design, would serve to elucidate the biological mechanisms of these diseases and could relate information concerning risk factors and preventative measures for all the diseases concerned.

One of the aims of this portal, is to create a supportive environment in which learners can assimilate information and, through the process of play, construct their own ideas about how HIV is transmitted. The game itself will contain various puzzles designed around the structure, pathology and transmission of HIV. Tuberculosis is another disease that needs to receive some attention. The stigma of TB in this country is powerful because of the public's fear of infectious diseases, and the lack of knowledge about TB only fuels this fear (World Health Organisation, 1998). Without increased education on TB and its cure, control efforts will be hampered across all cultures and regions of the world. Malaria is no kinder than tuberculosis and is one of the most prolific tropical infectious diseases known to man. Especially because of the endemic nature of this disease, and its constant threat, people need to be educated about possible preventative measures in order to be capable of making a difference.

## **2.3 Determining knowledge levels in learner population**

Having determined the diseases on which the study would focus, it became pertinent to determine pre-existing levels of knowledge pertaining to HIV/AIDS, malaria, tuberculosis and cancer present in the learner population for which this portal would be designed.

Collecting information from a group of individuals or a population can be carried out in a variety of ways, including questioning, either through an interview or a self-administered questionnaire (Joubert and Katzenellenbogen, 1997). A self-administered questionnaire would usually be filled out by the respondent while the researcher remains available to answer any questions related to the structure or phrasing of the survey questions (Joubert and Katzenellenbogen, 1997). For each study, the type of measurement instrument used depends on a number of factors, among which are the types of population under investigation, the type of information needed from the survey and the human resources or time available for the study (Joubert and Katzenellenbogen, 1997). Hence these factors needed to be considered in planning the survey.

Self-administered surveys are the most practical and cost-effective methods employed by researchers and are particularly well suited to polling larger populations (Babbie, 2001). They can be effectively used for descriptive, explanatory or exploratory purposes (Babbie, 2001). Questionnaires are most commonly used to collect information or attitudes representative of a population, within the limits of random error (Bartlett *et al.*, 2001). However, like all survey research, questionnaires have a few inherent weaknesses, including loss of important information through the standardization of questions, the poor manner in which social phenomena are explained, and possible inflexibility (Babbie, 2001).

Because of the suitability of the questionnaire tool for the type of information to be collected in this study, self-administered questionnaires were distributed to learners in their first year of study at the University of Natal, Durban. All respondents for this survey were between the ages of 17 to 22 years, making the sampled population consistent with the target learner group for the Virtual Learning Spaces Project (Amory, 2000).

## **2.4 METHOD**

### **2.4.1 Designing the questionnaire**

Based on the literature review of HIV/AIDS, malaria, tuberculosis and cancer, a number of knowledge areas concerning these diseases were identified as being poorly understood in the public domain. Knowledge concerning the biological agents behind these diseases and the mechanisms by which these agents spread

were not well understood. To enable the pertinent design of the survey questionnaire, these general knowledge areas were deconstructed into component concepts (Table 2.1), each dealing with a particular aspect of the lesser-known areas of the disease biology. Joubert and Katzenellenbogen (1997) state that unnecessary or unrelated questions should be avoided in optimal questionnaire design. Therefore, each component concept was addressed by one question in the initial questionnaire design, totalling twenty-one questions.

The first section dealt with the differences between viruses, bacteria and protists that are the causative organisms responsible for HIV/AIDS, tuberculosis and malaria respectively. The second section of the questionnaire posed questions related to HIV/AIDS, whilst the third concentrated on cancer. The penultimate section comprised questions regarding malaria while the final section focused on aspects of tuberculosis.

Whilst the questions pertaining to viruses, bacteria and protists (section 1) primarily addressed the areas of morphology and pathology of these causative organisms, the questions pertaining to any of the four diseases contained in the portal (sections 2 to 5) addressed aspects of transmission and prevention in these diseases.

Due to the non-threatening nature of this format (Fink and Kosecoff, 1985), the survey questions were designed as multiple choice questions. These authors suggest that multiple choice questions are preferable when compared with essay questions because they are best at measuring complex behaviours, can have more than one right answer and can be scored quickly and objectively (Fink and Kosecoff, 1985). The closed nature of multiple choice questions allows for more standardized data collection, but may also limit participant responses (Joubert and Katzenellenbogen, 1997).

In addition to each multiple choice answer, respondents were asked to record the confidence with which they regarded their answer to be correct. The purpose of this 'confidence rating' was to ascertain whether respondents simply did not know the correct answer, or whether they possibly had more serious misconceptions regarding the correct answer. Incorrect choices made with low confidence levels merely indicate gaps in knowledge, but incorrect choices with high confidence may point to a more serious misconception. Respondents specified their confidence level with the use of a four-point Likert scale situated directly beneath each question and labelled with appropriate descriptors, namely 'Not Confident', 'Slightly Confident', 'Fairly Confident' and 'Very Confident' (Figure 2.1). For the purposes of scoring respondent confidence, numerical values were assigned to each of the four alternatives (Likert, 1967), with low confidence equal to a value of 1 and high confidence equal to a value of 4. An even-numbered Likert scale was used to 'force' a choice and therefore minimize excessive selection of the neutral (mean) value usually evident in odd-numbered Likert scales (Joubert and Katzenellenbogen, 1997).

**Table 2.1** Table showing the assignment of different areas of knowledge regarding HIV/AIDS, malaria, tuberculosis and cancer into different concept categories.

Index No.	Concept Component
1	viruses reliance on host and ability to cause disease
2	bacterial independence, pathogenic ability and ubiquitous distribution
3	protist's pathogenic ability, life-cycle and distribution
4	HIV linked to AIDS
5	transfer of HIV
6	prevalent form of HIV transmission in Africa
7	condom usage, safe sex and the role of other sexually transmitted diseases in risk of contracting HIV
8	reliability and mechanism of the HIV/AIDS test
9	asymptomatic nature of HIV infected persons
10	symptoms of HIV infection
11	mechanisms of cancerous spread, including tumour progression, role of genetic mutations in cancer and abnormal apoptosis
12	causes of cancer
13	possible transmission routes of cancer, including inheritability
14	causative agent of malaria
15	transmission of malaria
16	virulence of different malaria strains
17	prevention of malarial transmission
18	causative organism of tuberculosis
19	transmission of tuberculosis
20	groups most at risk of contracting tuberculosis
21	role of environment in tuberculosis spread

The survey was required to be extremely clear and well laid out because untrained people would participate in this study (Joubert and Katzenellenbogen, 1997). Accordingly, the questionnaire contained a brief explanation stating the aims of the survey and concise instructions on what was required from the respondents (Fink and Kosecoff, 1985). The sequence of questions was planned in a logical manner, with each knowledge domain being dealt with in a separately identified sub-section, each of which was appropriately headed (Joubert and Katzenellenbogen, 1997) facilitating easy answering. Immediately after the introductory text respondents were asked to provide basic demographic information. According to Katzenellenbogen and Joubert (1997), this information is usually unthreatening and should be asked first in a questionnaire to get a better response from a sample.

12. Having unprotected sex on a frequent basis with different partners increases your risk of contracting HIV/AIDS.

(a) True

(b) False

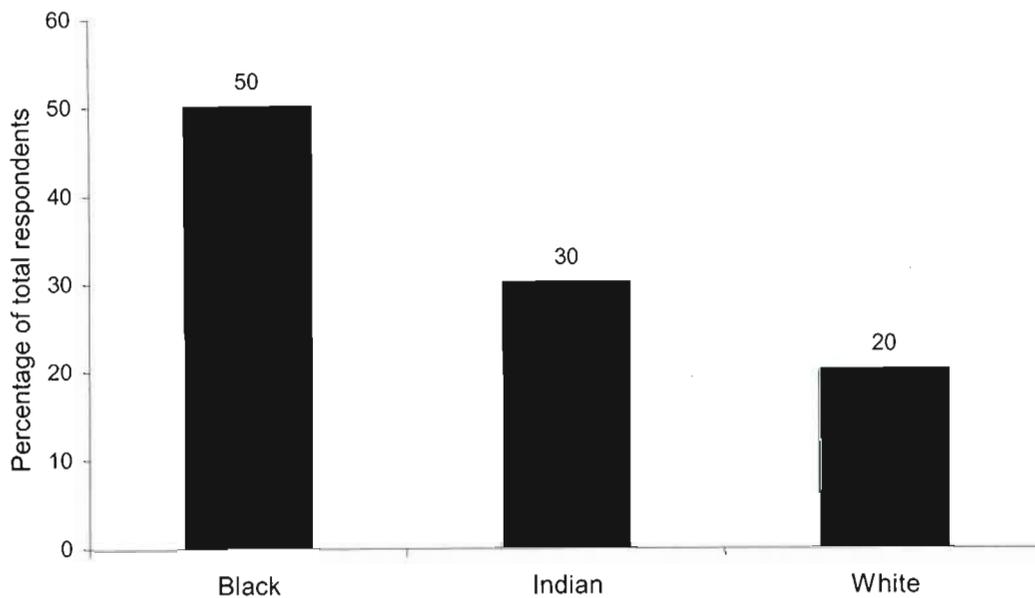
Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

**Figure 2.1** An extract from the final questionnaire depicting the format used and the incorporation of a four-point Likert scale.

#### 2.4.2 Piloting the questionnaire

Piloting a questionnaire involves delivering the questionnaire to a smaller sub-sample of people typical of the larger population for which the questionnaire was intended (Belson, 1986; Joubert and Katzenellenbogen, 1997). Self-administered questionnaires are heavily dependent on the clarity of their language (Fink and Kosecoff, 1985) and are therefore also dependent on pre-testing before general release. Through pilot testing, feedback can be obtained regarding any difficulties respondents had with the questions, and the effectiveness or clarity of any of the questionnaire instructions can also be assessed (Belson, 1986). Pilot testing can also help boost the response rate in the final questionnaire by making the questions clearer and therefore decrease the respondents' chances of becoming frustrated and leaving the questionnaire incomplete (Fink and Kosecoff, 1985).

Usually only between five and twenty subjects are chosen per pilot study (Joubert and Katzenellenbogen, 1997). In this study the pilot questionnaire was distributed to 36 students from various first year classes in the Science and Engineering faculties at the University of Natal, Durban. Respondents were asked to read the instructions and complete the questionnaire form in their own time. After completing the pilot study, a total of ten individuals were requested to discuss their views of the questionnaire design. Of these ten individuals, equal proportions of English second-language and English first-language speakers were included (Figure 2.2). This sample was also demographically and culturally representative of the most common race groups found on campus, namely black, Indian and white learners (University of Natal report, 2001). This was deemed important to ensure that the language used in the final questionnaire was concise and easily understood across the main cultures so as to not bias the final results.



**Figure 2.2** Percentage respondents that participated in the pilot study analysis. A higher proportion of English second-language speakers were asked about the suitability of the pilot questionnaire for distribution to a larger sample of the learner community. A total of 10 learners were asked their opinion of the pilot questionnaire, of which 5 were black, 3 were Indian and 2 were white.

### 2.4.3 Pilot questionnaire feedback

The main responses of the ten students were grouped and recorded against the frequency with which students made these comments (Table 2.2). The informal student opinions served as a qualitative assessment of the suitability of the pilot questionnaire.

**Table 2.2** The main student responses when asked their opinions on the pilot questionnaire.

Comment	Frequency of Responses
difficult questionnaire	70 %
questions too confusing	60 %
language too complex	40 %
terminology confusing	30 %
thought provoking questionnaire	10 %

The majority of the student's opinions indicated that the language and sentence construction were too complex for them to have successfully correctly answered some of the questions in the questionnaire. Some

of the students also found the terminology that had a biological slant too confusing. One student commented that the questionnaire was thought-provoking and required sufficient thought before answering.

#### **2.4.4 Defining the final questionnaire**

It was apparent from this qualitative analysis that the questionnaire needed remodelling before distribution to a larger sample of learners. Accordingly, the final questionnaire was simplified with simpler language, less confusing terminology and more concise sentence structure.

Simpler sentence construction was achieved by splitting previously long-winded questions into their component parts and posing each of these components as a separate question. Therefore, in order to include all relevant information, the final questionnaire consisted of a greater number of simplified questions (Appendix A) whilst still addressing the same knowledge domains.

#### **2.4.5 Defining the survey sample**

Probability sampling is the primary method of selecting representative samples for population research (Babbie, 2001). A sample is said to be representative of the total population if every member in that population has an equal chance of being included in the sample (Konijn, 1973; Joubert and Katzenellenbogen, 1997; Babbie, 2001). A sample can also be seen as representative of a larger population if the aggregate characteristics of the sample are a rough approximation of those in the population (Joubert and Katzenellenbogen, 1997; Babbie, 2001). In order to ensure that researcher bias, whether conscious or subconscious, does not affect the sample constitution, random selection of samples is essential (Babbie, 2001).

A well accepted type of random sampling is “stratified random sampling” wherein researchers have knowledge that strata of the population differ, in one of the measurement aspects of the survey, from the general population (Joubert and Katzenellenbogen, 1997). Stratified sampling allows researchers to draw on random samples from within each of the ‘groups’ present within a population, and draw conclusions about the total population from the inclusion of adequate numbers of these groups (Babbie, 2001). This technique allows researchers to maintain adequate representation of a sample.

In 2001 the University of Natal had a total of 23 909 students across four campuses throughout KwaZulu-Natal (Parliamentary Monitoring Group, 2001). To survey a statistically significant, representative proportion of the total University of Natal population, in excess of four to five hundred respondents would need to take part in the survey (Bartlett *et al.*, 2001), and be selected from all the faculties situated on the four campuses.

Such an approach was not practical and it was decided to obtain samples of the population through stratified random sampling procedures.

Since the content of the Virtual Learning Spaces “In the Service of Humanity” portal is largely of a biological nature, and the questionnaire was, in essence, testing for biological knowledge concerning these diseases, it was deemed important to have both respondents with, and without, formal academic biology training in order to ascertain what levels of knowledge existed in the general population. Stratified sampling would ensure that an adequate sample of biologists and non-biologists would be included in the survey.

One of the assumptions of this methodology was that if an aspect of an organisms biology was not well known within a sample of biologists, or ‘experts’ in the biology field, then that aspect of an organism’s biology would be less well known in the general population. A second assumption of this method was that any gaps in knowledge concerning these diseases would be consistent across both the biology and non-biology learner groups. By the inclusion of both biology and non-biology learners in the sample, this assumption could also be statistically tested.

To ensure a statistically valid and representative sample, surveys were carried out in three quantifiable strata within the Science and Engineering faculties at the University of Natal, Durban. Inclusion in the first stratum required learners to be registered for one of the biology major subjects. A total of 100 biology major learners were polled in this survey. Inclusion in the second stratum required learners to be registered for a non-biology degree within the faculty of Science. A total of 71 learners were polled within this stratum. Finally, inclusion in the last stratum required learners to be registered for a non-biology degree through the faculty of Engineering. A total of 86 students were polled from this stratum. Therefore, 100 biology learners and 156 non-biology learners were included in the sample using random sampling procedures.

In 2002, a collective total of 675 learners were registered for their first year of study in the Science and Engineering faculties at the University of Natal, Durban (University of Natal Statistics, 2002). According to Bartlett and colleagues (2001), a population of this size would require a sample size in the region of 235 to 249 respondents to be a statistically representative sample of the whole population. This calculation of sample size takes into account factors such as the categorical nature of the data being collected, an acceptable margin of error (5%) and an estimate of variance (25%) in the sample to give a confidence level of 95 percent (Cochran, 1977; Bartlett *et al.*, 2001). If the respondents are drawn from a homogeneous population (i.e. from one stratum), the sampling error for that sample is reduced to zero (Babbie, 2001), making the margin of error estimated at 5% over-cautious. After taking all of this into account, the number of respondents surveyed in this study amounted to 257 learners.

#### **2.4.6 Coding the data**

Responses to the final questionnaires were collated and the answers entered into a spreadsheet (Microsoft Excel) where they were prepared for comparative analysis. For each completed questionnaire the answers were categorized into two categories. The numeral '1' was assigned to correctly answered questions while '0' was assigned to incorrectly answered questions. For each answer, the confidence level that was specified by the respondent was recorded. Furthermore, the gender, age and faculty of each respondent was recorded. Once the data had all been entered, it was exported to a statistical program (SPSS 11.5 for Windows) for statistical analysis.

#### **2.4.7 Establishing representation of the sample**

The demographic numbers of the sample were totalled and graphed against the known first year intake figures for the Science and Engineering faculties. By comparing the demographics of the sample to the demographics of the student population in these faculties, it could be ascertained if the sample was truly representative of the population from which it was drawn.

#### **2.4.8 Testing biology learner versus non-biology learner knowledge**

In order to test the assumption that learners with formal academic biological training would have higher levels of knowledge than learners without biological training concerning these diseases, the percentage of correct answers from these two groups were compared for each concept component category using an independent samples T-test. This statistically descriptive procedure verified if any difference existed between the two mean populations, as well as tested the degree of correlation between these populations. From these results, the assumptions could either be affirmed or negated.

#### **2.4.9 Describing gaps in knowledge across the respondent population**

Analysis was carried out across the entire sample and descriptive cross-tabulation statistics were used to describe the proportion of correct responses to each question, as well as the range of confidence levels specified for each answer. This descriptive method was particularly well suited to elucidating areas of knowledge where large numbers of the sample answered questions incorrectly and did so with high confidence levels in their answers. The learning objectives for this study were derived from the areas of knowledge that were shown to be lacking across the entire sample, and higher priority was given to those questions that were frequently incorrectly answered, with corresponding high confidence levels.

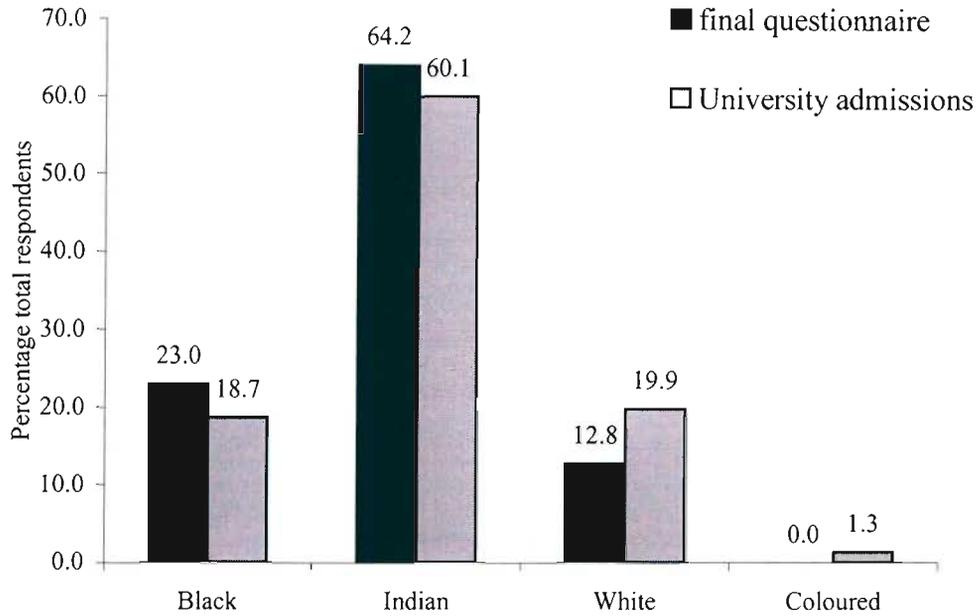
## 2.5 RESULTS

### 2.5.1 Representation of the sample

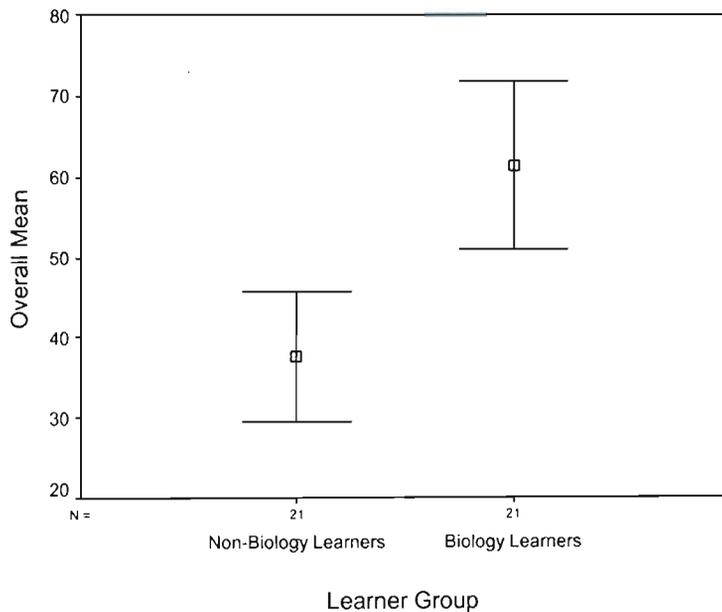
The graphical comparison (Figure 2.3) showed that black (+4.3 %) and Indian (+4.1 %) learners were slightly over-represented in the sample, whilst white (-7.1 %) and coloured (-1.3 %) learners were slightly under-represented. Despite these differences, the sample population was found to be demographically representative of the first-year learner population in the Science and Engineering Faculties at the University of Natal, Durban. To confirm this, a paired-samples T-Test was conducted between the two data sets and they were found to be significantly correlated (Pearson correlation: 0.985;  $N = 4$ ;  $P = 0.015$ ).

### 2.5.2 Testing for compatibility between biology and non-biology learners

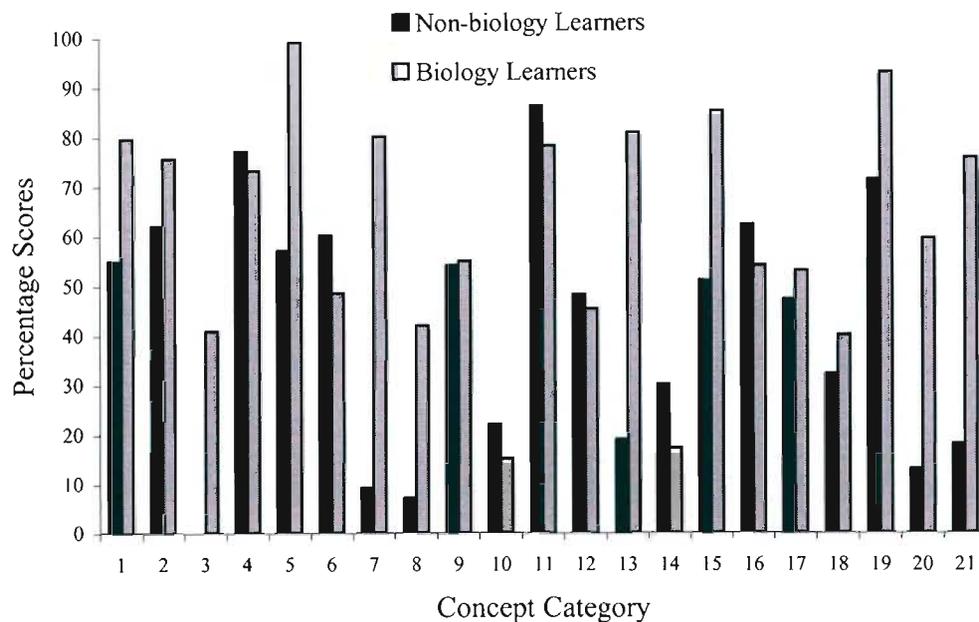
The responses for learners with and without biological training were averaged per concept category and subsequently compared using a paired-samples T-test. An assumption of the T-test is that the two populations of data being compared are normally distributed. This normal distribution was confirmed using a Kolmogorov-Smirnov test (Non-biology learners:  $P = 0.796$ ;  $N = 21$ ; Biology Learners:  $P = 0.585$ ;  $N = 21$ ). The T-test revealed that the two data populations were significantly different ( $P < 0.001$ ;  $DF = 20$ ) with the non-biology learners scoring, on average, 23.8% lower than the biology learners (Figure 2.4). This was an expected result since the questionnaire was primarily testing the biological knowledge that respondents had concerning these diseases. However, apart from the differences in the mean scores of both comparison groups, both groups were found to be significantly correlated (Pearson correlation: 0.589;  $P = 0.005$ ;  $N = 21$ ), showing that non-biology learners and biology learners had problems or scored well on the same concept categories (Figure 2.5).



**Figure 2.3** The learner population polled in the final questionnaire. The demographics of students that were polled in the final questionnaire compared to demographics for the Science and Engineering faculties at the University of Natal, Durban (2002). Black and Indian students were slightly over-represented while white students were slightly under-represented, with coloured students not being represented at all. The demographic pattern from the survey sample was statistically correlated to the official University intake figures for 2002 (Pearson correlation: 0.985; P = 0.015).



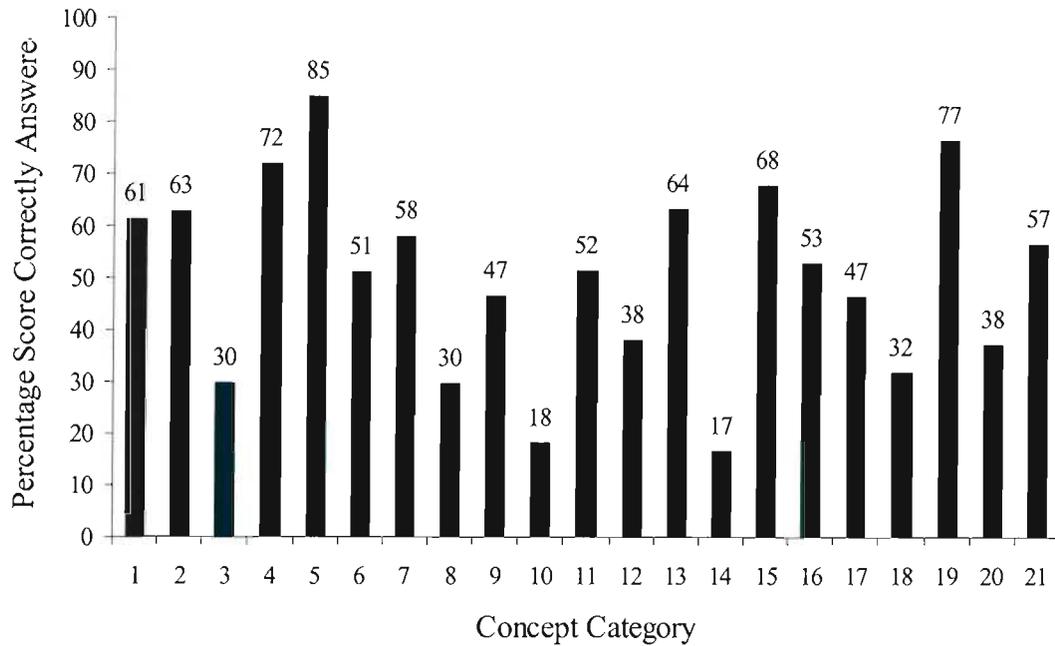
**Figure 2.4** The mean questionnaire scores for all questions in biology and non-biology learners. Scores were significantly different between the two populations. Overall, biology learners scored 23.8 % above their non-biology learner counterparts. (Biology learner mean = 61.4 %; Non-biology learner mean = 37.6 %; T-Test P value < 0.001; DF = 20).



**Figure 2.5** Average scores for biology versus non-biology learners for each concept category of the questionnaire. The averages calculated per concept category for biology- and non-biology learners within the Faculties of Science and Engineering at the University of Natal, Durban. Both data populations were significantly different from one another (T-Test  $P$  value  $< 0.001$ ;  $DF=20$ ), yet were significantly correlated (Pearson correlation co-efficient = 0.586;  $P = 0.005$ ;  $N = 21$ ). This demonstrated that whilst the biology learners scored higher overall, both populations appeared to struggle, or excel, in the same concept categories.

### 2.5.3 Full questionnaire analysis

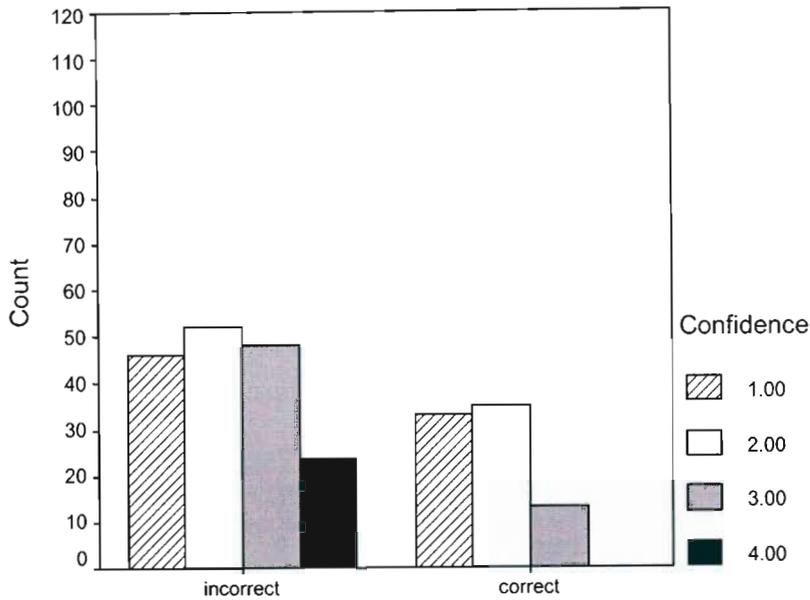
Responses from both biology- and non-biology learners were combined for this part of the analysis. The level of knowledge for each concept category was generally low with few exceptions. The mean percentage for all learners combined was 49 % inclusive of all concept categories. When comparing learner performance in the questionnaires, it was clearly apparent that many gaps in knowledge existed within this target audience (Figure 2.6). Most notably, an average less than 50 % was achieved in just less than half of the concept categories, with an average of less than 40 % being achieved in a third of the concept categories.



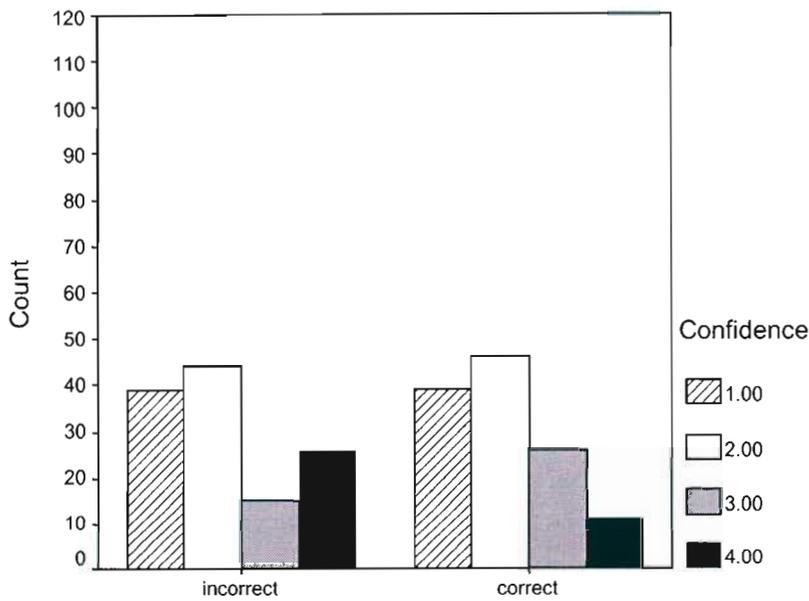
**Figure 2.6** Graph showing the percentage score averages for all respondents in the survey. All responses were averaged per concept category. The majority of the percentage scores for the respondents were low, with only a few questions being generally well known across the sample. This graph shows a mean score of 49 % overall, indicating that respondents had a marked lack of knowledge concerning the biological aspects of HIV/AIDS, malaria, tuberculosis and cancer.

#### *Viruses, Bacteria and Protists*

Knowledge concerning viruses (61 %) and bacteria (63 %) was not high and knowledge concerning protists was poor (30 %), with 70 % of respondents answering the two questions based on protists incorrectly and with low confidence levels (Figure 2.7).



Question 6: Knowledge of Protists

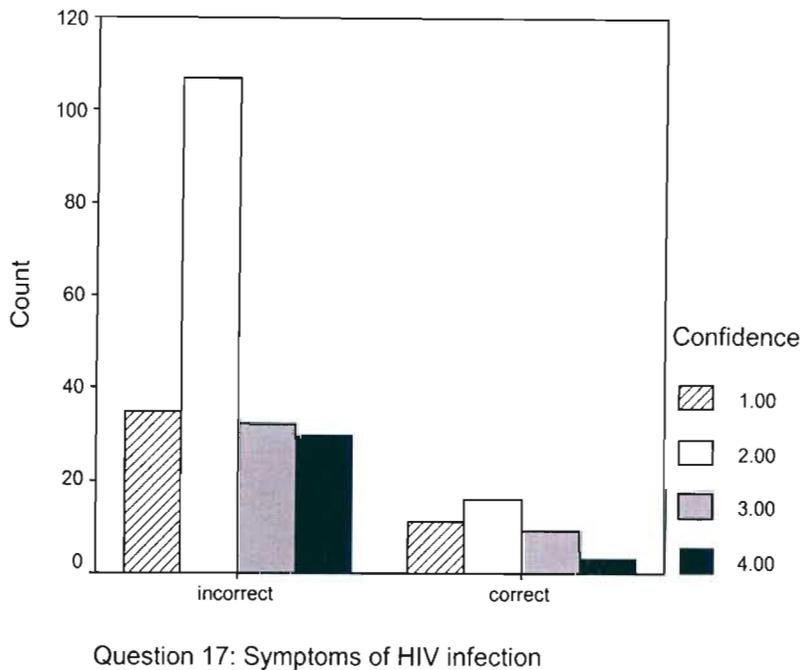


Question 7: Knowledge of Protist life cycles

**Figure 2.7** Learner knowledge concerning protists. Cross-tabulation analysis of Question 6 shows the majority of answers provided were incorrect and had higher average confidence levels. Question 7 shows a mixed response with a few respondents specifying higher confidences in the incorrect answer. High confidence in these incorrect answers may indicate a more serious gap of knowledge concerning protists.

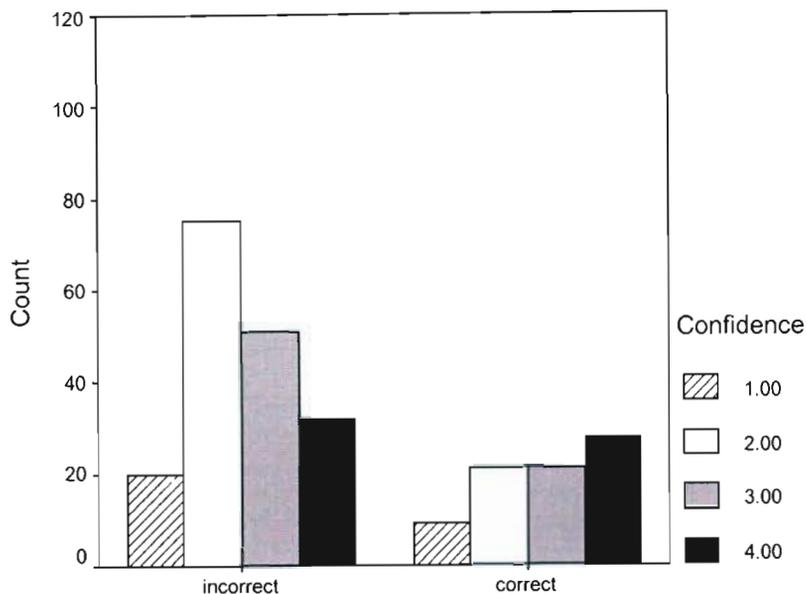
## HIV/AIDS

Knowledge was second-lowest for the symptoms of HIV infection (concept category 10), with an average of only 18 % for this category (Figure 2.8). Of the 88 % of learners who answered this question incorrectly, most did so with low confidence levels, indicating a basic lack of knowledge regarding the symptoms of HIV infection.

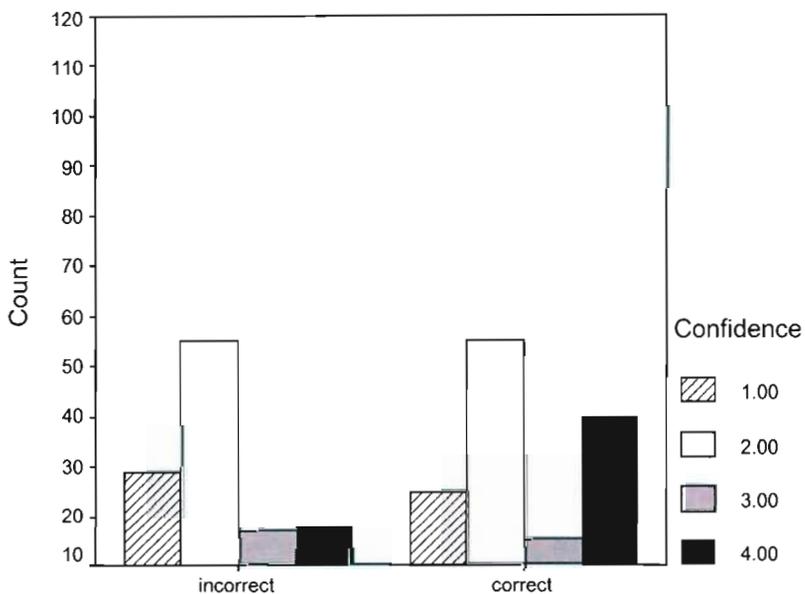


**Figure 2.8** Levels of awareness in symptoms of HIV infection. Cross-Tabulation of Question 17 showing the majority of incorrect responses, but also the relatively low confidence in these answers. This indicates that most respondents were unaware of the initial symptoms of HIV infection. This type of knowledge could be very important in empowering individuals for self-awareness and possible future preventative action.

Knowledge about the HIV/AIDS test was generally poor (30 %) (Figure 2.9). Issues concerning safe sexual behaviour were better known (58 %), whilst awareness of the major mode of HIV transmission in Africa was only known by half the respondents (51 %). The question concerning externally visible symptoms of HIV was not well answered (47 %) and learners also demonstrated a lack of knowledge concerning the personally discernible symptoms of HIV infection (18 %). Knowledge of the latter could play an important role in self-regulating health behaviour and could result in more frequent HIV testing and improved use of preventative methods. In this survey, learner knowledge concerning the link between HIV and AIDS (72 %) and the method of HIV transmission (85 %) was comprehensive.



Question 14: Reliability of the AIDS test

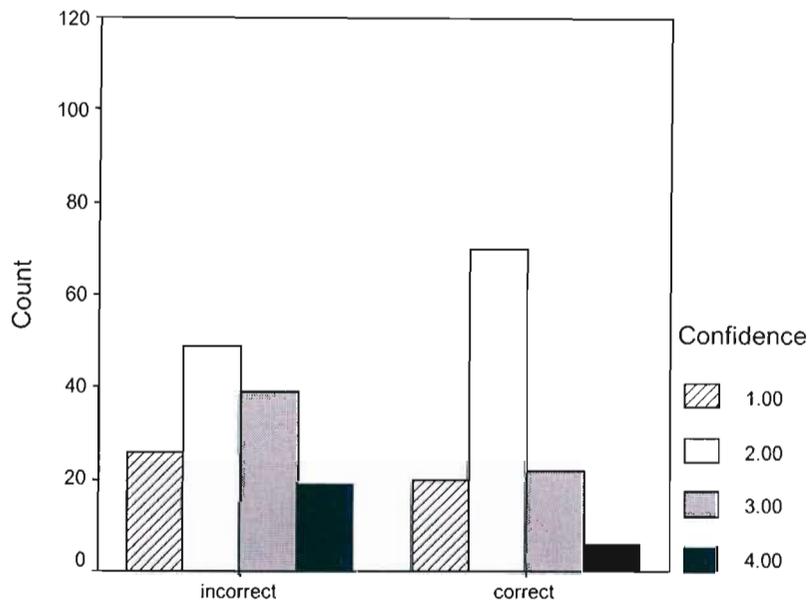


Question 15: Mechanism of the AIDS test

**Figure 2.9** Learner conceptions of the reliability and mechanism of the HIV/AIDS test. Cross tabulations showing the relationship between answers and the confidence levels as provided by respondents. Approximately half the respondents knew about the mechanism of the AIDS test, yet many were unsure of their answers in both the correct and incorrect categories. Respondents not only demonstrated a lack of knowledge concerning the reliability of the AIDS test, but also did so with comparatively higher confidence levels.

## Cancer

Although knowledge concerning cancer progression within the body, and the role of tumours in this progression, was known by only half the respondents (52 %), possible routes for cancer transmission were better known (64 %), The causes of cancer, however, were clearly not well understood (38 %) (Figure 2.10).

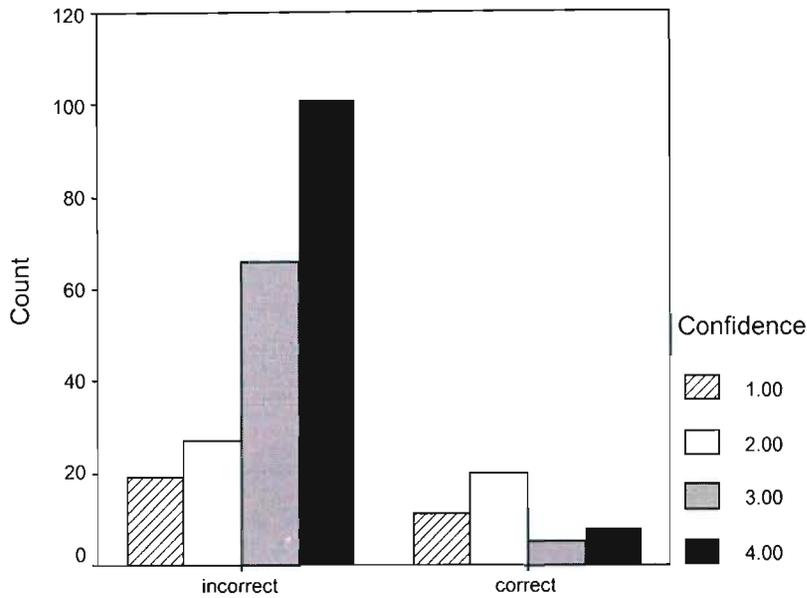


Question 22: Causes of Cancer

**Figure 2.10** Learner knowledge concerning causes of cancer. A large number of respondents specified the incorrect answer about the causes of cancer. Approximately only ten percent of all respondents were confident in their answers, with the majority being largely unsure. This demonstrates a basic lack of knowledge concerning the causes of cancer.

## Malaria

Learners did not know what the causative organism of malaria was (17 %) and consequently this concept category attained the lowest score in the questionnaire. Whilst learners scored substantially higher in the aspects of malaria transmission (53 %), the virulence of different malaria strains (53 %) and knowledge of malaria prevention (47 %) the overall section on malaria was generally poorly answered (Figure 2.11).

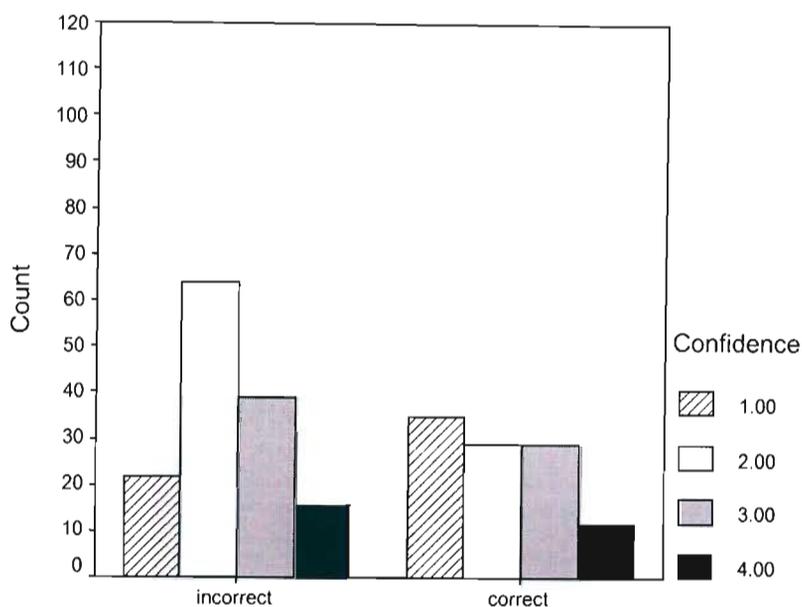


Question 24: Causative organism responsible for malaria

**Figure 2.11** Learner knowledge concerning causative organism of malaria. The majority of responses were incorrect when identifying the causative organism of malaria. Respondents generally displayed a lack of knowledge regarding the biology of malarial disease. Most incorrect answers were given with high confidence levels.

*Tuberculosis*

Tuberculosis was the least familiar disease to the learners overall (Figure 2.12). The only aspect learners were well familiar with in this section was the spread of tuberculosis via an infected person (77 %). Other aspects of tuberculosis, such as the causative organism responsible for tuberculosis (32 %), the conditions in which tuberculosis is most likely to persist (57 %) and thus the group of people tuberculosis is most likely to affect (38 %) were generally not well known.



Question 28: Causative organism for Tuberculosis

**Figure 2.12** Mixed learner response concerning the causative organism responsible for tuberculosis. The majority of learners specified the incorrect answer and were moderately sure of their choice, with only a small percentage of learners specifying the correct answer with high confidence levels.

## 2.6 DISCUSSION

### 2.6.1 HIV/AIDS

One of the poorest areas of knowledge amongst learners concerned the symptoms of HIV infection. Only 18 % of learners answered this question correctly, and this was the second-most poorly answered question in the survey. This particular question referred to the symptoms that are not necessarily visible to other people, but rather to an individual experiencing the symptoms. Most respondents in the study did not acknowledge that minor symptoms become apparent after the initial window period has passed in HIV infection. This is understandable since most of the AIDS awareness programs focus on the fact that people with HIV infection appear asymptomatic to others whilst little is mentioned about the minor symptoms that do manifest. The literature shows a more pronounced knowledgeable response than the one recorded here. A study conducted in 2002 (UNICEF *et al.*, 2002) claimed that only 50 % – 74 % of girls between the ages of 15 and 19 know a healthy looking person can have the HI virus.

Nearly three quarters of learners knew that HIV causes AIDS, although this figure should theoretically be higher given the recent level of exposure to this issue in the media. In the question probing this topic, the

majority of respondents specified that HIV causes AIDS, and the remaining 25 % thought that HIV and AIDS may have been linked, but that HIV didn't necessarily cause AIDS. This view was debated quite hotly for some time in this country with prominent public figures questioning the link between HIV and AIDS (Tshabalala-Msimang, 2002), and therefore may possibly have caused confusion in learners.

The majority of learners knew that HIV was sexually transmitted. This is encouraging as this knowledge can help people to modify their risky behaviour and possibly protect themselves from such infection. In a study conducted amongst black South African youths (Richter, 1996), a high level of HIV/AIDS awareness was demonstrated but, unlike in this questionnaire, most respondents were unaware that HIV was sexually transmitted. Disparities between the results of the study by Richter (1996) and the results of this survey could be due to the prolific number of HIV/AIDS awareness campaigns in recent years, or could be a function of the level of education attained by respondents. This is quite likely because the original study was conducted in a population without much formal education (Richter, 1996). The average age of the respondents in the 1996 study was also lower than those targeted in this study, and life experience and maturity may play a role in knowledge acquisition and behavioural change. More recently, a study conducted by the Department of Health (1999) reported that ninety-seven percent of women attending antenatal clinics in South Africa demonstrated knowledge of HIV/AIDS.

The major mode of HIV transmission in South Africa was generally not well known. In this question, 37 % of learners thought that mother-to-baby transmission was the major route of HIV infection. This could be due to the political awareness that has been created around the issuing of Nevirapine to pregnant HIV-positive mothers in the press throughout 2001 and 2002 (Rickard, 2002; Tshabalala-Msimang, 2002). Knowledge of the main route of transmission in this country is important if the pandemic is to be stopped. People need to know the facts so they can take appropriate action in their own lives. In numerous studies people have thought themselves to be at minimal risk to HIV infection (Richter, 1996; UNICEF *et al.*, 2002) when, in fact, these people have been in the highest risk group practicing sexually risky behaviours. The studies showed that their complacency was not based on ignorance because they demonstrated knowledge of HIV and HIV transmission. The concept of heterosexual transmission in Africa needs to be emphasised.

In connection with sexual transmission, learners showed that 58 % of them were aware about aspects of condom use, safe sex and the role of other sexually transmitted diseases in contracting HIV. This level of awareness is surprisingly low when compared with other studies looking at the awareness of HIV transmission. In the Department of Health's study (1999) as many as eighty-seven percent of respondents knew that condoms could help to protect against HIV/AIDS, but only 22 % of the sexually-active women aged 15 – 49 ever used a condom, and only eight percent had used a condom during their last intercourse.

Finally, learners demonstrated a limited understanding of the HIV/AIDS test and the principles behind it. Only 42 % knew the AIDS test is not always completely accurate, or the premise on which the AIDS test operates. Details concerning this test and its accuracy will be included in the portal.

### **2.6.2 Tuberculosis**

The causative organism of tuberculosis was not well known, with 32 % of the respondents answering this question correctly. The reason for this could be two-fold: firstly, few educational programmes go beyond explaining the symptoms and risks of tuberculosis and secondly, until fairly recently, tuberculosis has not had a great deal of public exposure in this country. Because of the social stigma concerning infectious diseases people generally do not communicate about tuberculosis (World Health Organisation, 1998). This stigma is a result of the lack of knowledge regarding tuberculosis and the fear that is borne out of this incomplete knowledge. This lack of communication has started changing recently because of the increase in HIV infection rates and the linked increase in tuberculosis incidence. HIV and tuberculosis programmes should become more integrated because of their increasing rate of co-infection (Anderson and Maher, 2002).

Other information concerning tuberculosis, such as the mechanism of tuberculosis transmission and the conditions that enhance the spread of tuberculosis were generally well known. The concept of tuberculosis being contagious was most notably recognised by the learners and 92 % of the respondents correctly answered this question.

### **2.6.3 Malaria**

The causative organism responsible for malaria was not at all well known, with this question returning the lowest percentage of correct answers (17.2 %) for the study. This is expected in light of the fact that learners generally did not know what protists were (see section 3.4.5). Learner knowledge surrounding the transmission of malaria was substantial with 68 % of the respondents correctly answering this question. However, knowledge concerning the virulence of different malaria strains (53 %) and more importantly, the prevention of malaria transmission (47 %) was inadequate. Whilst a major emphasis seems to have been placed on educating people about malaria in programs elsewhere, it appears that the policy in South Africa is more geared toward removal of the vector and a much smaller component geared towards education (Sharp *et al.*, 2000). Perhaps this could account for the poor knowledge concerning factors such as prevention and the causative organism of malaria. In an effort to address this situation, one of the aims of the portal will be educate learners further about malaria.

#### 2.6.4 Cancer

Of the three concept categories testing for cancer knowledge, two of them were generally better known than the third. The first of these concerned tumour progression, the inheritability of cancer and the ability of cancerous cells to live abnormally long life spans and was known in 52 % of all learners. The second category concerned the possible transmission routes of cancer, and this was known in 64 % of learners. The concept category that was not well known by learners was that which dealt with the causes of cancer in which only thirty-eight percent of learners answered the question correctly.

These results indicate that learners were not familiar with many of the general biological mechanisms behind cancer. This issue should be addressed because only through the knowledge of what causes cancer, and how it can be detected in the early stages, can learners take evasive action. Previous studies have shown the link between education programmes and an increased awareness in the public concerning cancer. Sukardja and Asmino (1983) reported that the number of early cancer admissions (stage I and stage II) compared with advanced cancer admissions (stage III and stage IV) in a hospital in Indonesia doubled when the public were involved in a local education programme. This education programme was based on showing the public what the symptoms of early cancer disease were and focussed on self-administered health checks that the public could execute, therefore taking responsibility for their own health care. From these results, it is clear that people in this study benefited from the knowledge they acquired about cancer in the educational programme.

Neither of the cancer concept categories from this study were well answered and this shows a need where education regarding cancer can be delivered to learners. Consequently, one of the learning objectives of this portal will be to facilitate learning about the causes of cancer and some of the basic principles behind cancer.

#### 2.6.5 Viruses, Bacteria and Protists

The results of the questionnaire show that learners are not unfamiliar with the concepts of viruses. Approximately two thirds of the learners knew basic details about what was defined as a virus, and a similar number of learners also knew the basic biology of bacteria. Widespread basic knowledge of bacteria and viruses is to be expected as both these organisms are frequently referred to in the media or major health programs. Surprisingly, learners appeared to have knowledge about the living requirements of viruses and bacteria which is not often an aspect of their biology which is discussed.

Because protists are merely the subject of biology lessons, they do not attract any media hype. In the case of malaria, the only organism publicised in prevention campaigns is the *Anopheles* mosquito (Sharp *et al.*,

2000). This is understandable as in the major health programs run in malaria endemic areas (for example the Department of Health and World Health Organisation programs) all preventative measures are directed at stopping the breeding of, and contact with, these mosquitoes. Consequently, the questionnaire analysis showed only thirty percent of learners to have an idea of what a protist was – that was less than half the number of learners who had knowledge of viruses and bacteria.

A focus of the portal would be to highlight the role of protists in malaria and to highlight the life-cycle and how this life-cycle relates to aspects of malaria transmission and prevention.

## **2.7 CONCLUSIONS**

The results of this survey indicate that learners were generally aware of aspects related to routes of transmission in these diseases, but were in some cases acutely unaware of the biological entities responsible for the diseases. Strangely enough, information pertaining to the prevention of these diseases was often inadequate and naive, and hence this serious issue was chosen to be pursued in this portal. Knowledge regarding two of the three micro-organisms discussed was generally good, with knowledge of the third (protists) not widespread.

### **2.7.1 Definition of learning objectives**

The survey showed aspects of the biology and prevention of these diseases that need to be addressed in an educational format. One of the problems facing education on diseases today is that people do not readily put what they know about disease prevention into practice, because often people have a low perceived risk of infection. Therefore, if this information is delivered to learners in a more contextualised and enjoyable manner than has been traditionally done in the past, the chances that learned knowledge will be used in everyday life is increased.

Based on the results of the survey as well as information from a review of the literature, the learning objectives for the portal were defined as:

- the transmission, biology, symptomatic expression and prevention of HIV, malaria and tuberculosis;
- the biology and mechanism of cancer;
- the exploration of viruses, bacteria and protists, with special focus on the differences between viruses and bacteria and the role of protists in malaria; and
- the exploration of all the learning objectives in a constructivist situated learning environment where the learners' willingness to learn becomes their motivating force to play the game.

It is hoped that by transforming and constructing this information in the context of the portal, learners will gain a deeper understanding of these diseases. As a result of this deeper understanding, it is hope that this information will be more readily retrievable by learners in every day situations and could therefore play an important role in future self-regulating preventative action.

## CHAPTER 3

### STORYLINE DESIGN AND TESTING

#### 3.1 Introduction

After the definition of the learning objectives, the next step in the game design process is the definition of the storyline. Both a story workshop and focus group meetings were held to negotiate the storyline within a diverse group which was broadly representative of the target learner group. The Game Achievement Model was closely associated with this design process and was evaluated, through a process of inquiry and reflection, for its usefulness in this process. Strengths and weaknesses of the GAM will be elucidated. Finally, the storyline will be described as well as the procedures used to test for its effectiveness and suitability.

##### 3.1.1 Importance of a story

Educational puzzles are effective mediators of learning, but they would be more effective in combination with a storyline exciting enough to motivate learners to want to engage with the puzzles, play the game and learn in the process.

Motivation can either be an extrinsic (external) or intrinsic (integral) factor to learner environments (Reeves, 1995). In more traditional teaching methodologies, extrinsic motivation is often used which is, for example, the need to perform tasks or learn a knowledge domain to be awarded class marks (Rieber, 1996a). On the contrary, activities are said to be intrinsically motivating when learners continue to participate despite the removal of external pressures (Deci, 1975). According to Keller and Suzuki (1988) learners will only be committed and persevere in a task if they deem the conclusion to be personally satisfying.

Games represent one way in which learners can be immersed in a constructivist learning environment (Amory, 1998). Games also promote imaginative engagement and can promote fun in learning. Because of this, games offer a powerful format for educational environments that are attractive as well as motivating to learners (Boyle, 1997). Rieber (1996a) recommends that designers of educational environments should provide a meaningful learning context as this supports intrinsic motivation and self-regulated learning. Fantasy games offer a very personal fascination and intrigue and, as such, have the ability to provide learners with meaningful contexts for learning (Rieber, 1996). Further, Malone (1981a) describes the three characteristics of intrinsically motivating environments as challenge, curiosity and fantasy. An appropriate storyline in a contextualised environment can make the game challenging, create curiosity and include elements of fantasy.

An appropriate storyline also provides learners playing the game with a mission. This supports what Savery and Duffy (1995) propose for problem-based learning in that all learning activities should be anchored to a larger task or problem. A mission can be described as the overarching goal of the learner environment (Wilson and Cole, 1996). The mission of a game might be to take on the role of a character and do what they would do within the context of the game, thereby learning any skills that character would need to use in its interactions with the gaming environment. Alternatively, learners could rather play the game to achieve a specific objective, and learn various skills along the way (Wilson and Cole, 1996).

Laurel (1990) suggests that principles of effective drama can be adapted to the design of situated learning environments. More specifically she states that a dramatic approach to structuring a situated learning experience has significant benefits in terms of engagement and emotion. The more learners are engaged with a learning environment, the more intrinsically motivated they appear and therefore, the more likely to engage in self-regulated learning behaviour (Rieber, 1996).

Therefore, whilst educational puzzles embedded arbitrarily within an educational environment may well still, within themselves, achieve the ends for which they were intended, the reality is that without a story context in which to embed these puzzles, few learners would have the motivation to pursue them. In addition, without a story or mission, learners are not likely to see the game as being relevant or completion of the game as satisfying, and are therefore not likely to play the game in its entirety (Lepper, 1985).

### **3.1.2 Design of the storyline**

One of the base tenets of constructivism is that learners build knowledge through the process of social discourse (Choi and Hannafin, 1995). Because this portal was to be designed in a constructivist framework, it was decided to extend the ethos of social interaction and collaboration to the storyline development process. It was therefore important that all stake-holders in the game design process interacted and participated in designing a storyline that would be universally acceptable. However, when engaging with many people, all with different opinions, personal backgrounds and cultures, it can become increasingly more difficult to negotiate a story that is seen as relevant by all concerned and still encompass the learning objectives for the portal. It was because of this fact that a model, the Game Achievement Model (Figure 1.2; p. 20), was used as a template in the design of the storyline.

### 3.1.3 Story workshop

In order to facilitate the construction of a storyline that was universally acceptable to all stake-holders of the game design process, a story workshop was held. In this meeting the pre-determined learning objectives were made known to all sixteen members present, before ideas for an adequate storyline were discussed amongst the group. Interested members represented various cultural and religious backgrounds inherent in South Africa and this, therefore, ensured that the story was culturally sensitive. This group was also given the mandate that all stereotypes, such as gender-based subjugation and racist-based issues, should be reasonably avoided in the making of this story. The workshop lasted approximately 90 minutes and was recorded onto an audio tape and later transcribed. NVivo (QSR), a qualitative data analysis package, was then used to organise the data and query it for any trends. In this way, the data was used to analyse how people responded to the GAM, or the concept of using the GAM, in designing the game storyline.

The story workshop was a fascinating process with topics as diverse as racism, sexism, imperialism and capitalism being discussed alongside issues such as environmental disturbance, disease, cures, control and communication. The story workshop began with the presentation of the learning objectives for the game. The participants were then informed that whatever storyline emerged from the workshop would have to encompass the learning objectives and ultimately facilitate the realisation of these learning objectives. The development of the storyline, however, was completely up to those present at the workshop to negotiate.

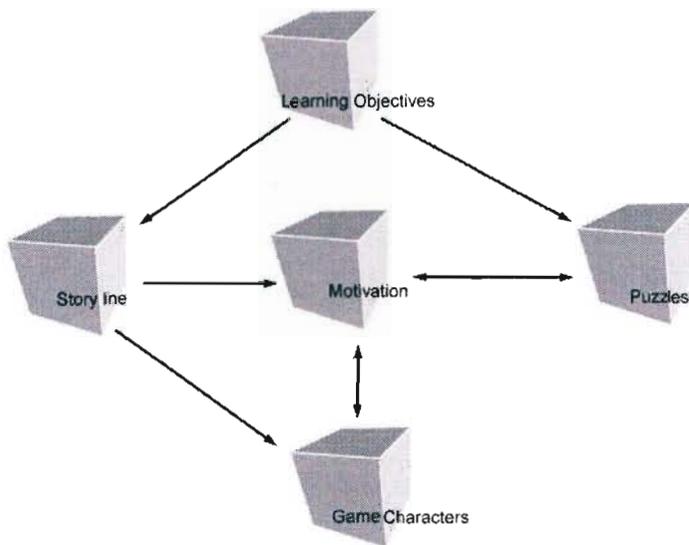
Upon inspection of the workshop transcript, a pattern emerged. The discussion started at a very broad level with individual members submitting various different ideas for discussion, followed by a fair amount of conjecture between members. However, once the members had agreed on a location for the game setting, the exchange became a lot more refined and headway was truly made. Finally, after one hour and forty-five minutes, the members of the workshop reached an agreement, and decided on a basic storyline.

The strength of this stage of the GAM was provided largely by pre-stating that the storyline had to encompass the realisation of the learning objectives (Figure 3.1). Because of this, the initial scope of the storyline was confined to manageable levels. By constantly comparing the emerging story to the learning objectives throughout the process, the final story was both feasible and practical.

Another real strength of this step of the process was the diversity of the members that attended the workshop. The process helped the realisation that everyone had a different background and different people considered different things offensive or not. Many times during this workshop it was realised the issues that were

inconsequential for some, were more important to others. This rounded view was necessary in the planning of a game that will be played by a large multicultural audience.

Once the basic storyline had been agreed upon, the writing of the story script started in earnest. To carry out this task, a smaller focus group was formed to take the initial step of the model further.



**Figure 3.1** A model showing the importance of the learning objectives in defining the story. Paramount to the success of the model is the definition of the learning objectives at the outset. This enables members of the design team to start from a common understanding and has a direct impact on the storyline and puzzle design. These factors, along with the game characters in the level, affect the motivation of the player. The good understanding of learning objectives makes for good story design which, in turn, makes the game more relevant and interesting, and therefore positively affects player motivation.

### 3.1.4 Focus group

After the story workshop in which participants had made their suggestions, a focus group consisting of a script-writer, a graphic designer and the portal subject researcher was formed. The purpose of this group was to take the general storyline, as defined in the workshop, and refine it, dividing it among appropriate scenes and making it more congruent with the learning objectives for the portal

The focus group was where most of the hard conceptualisation and planning work took place. It was this group of three people, each with different areas of expertise, that decided on the more detailed version of the story-line, the specific acts and specific scenes for the game. This group of people worked a lot more closely with the GAM than any other, and were required, more than any other, to align their thinking with that of the GAM.

The process this group followed was of defining different acts that would occur within the game, and then defining the learning objectives that should be realised in each act. In addition to this, individual scenes were then defined, with each scene in the act contributing to the realisation of the learning objectives for that act. Scenes were defined as individual geographic locations within the game and were scripted with appropriate puzzles and objects to realise the learning objectives.

The scripting process was iterative with constant review and revision with each meeting of the focus group. In this way, the three members negotiated a more specific storyline amongst themselves with, once again, these different members bringing something unique to the process.

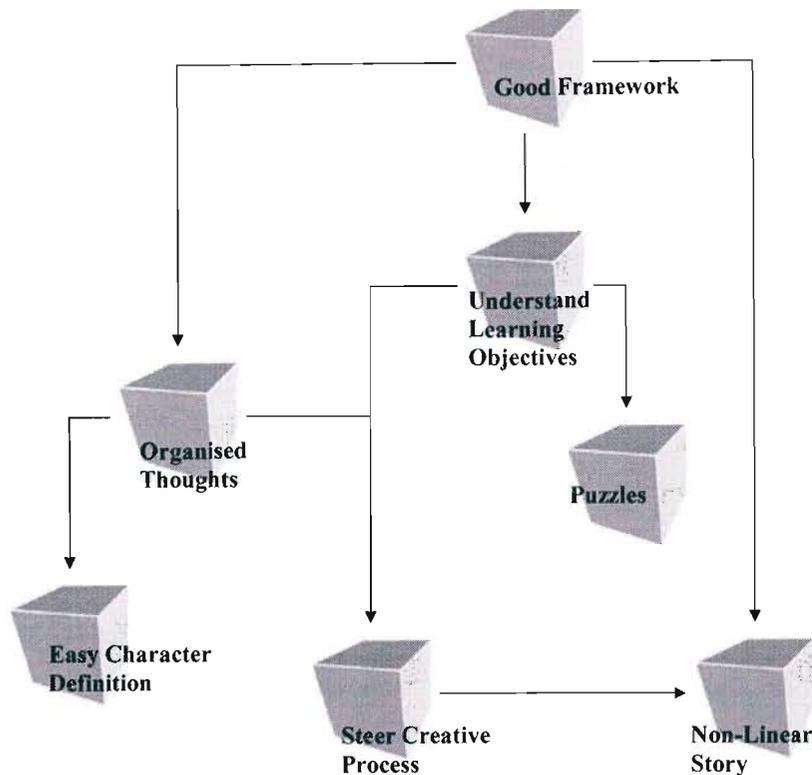
As a result of approximately five separate meetings, the game was fully documented with three acts, seven scenes and a number of educational puzzles to enable realisation of the learning objectives. Throughout these meetings, the GAM was used as a guideline, and made conceptualisation of the overall level much easier.

After the story was documented in its final form, the people involved in this process were interviewed on aspects of the process. Their answers and opinions were recorded and organised using the qualitative data analysis package, NVivo.

The members found the GAM to be a useful tool in that it provided a good framework structure around which the group's thoughts could be organised (Figure 3.2). The structure provided the team with a good starting point and steered the creative process in the right direction. This wouldn't have been possible if the scripting had been attempted with no structuring.

It is central to the model that all members of the story-writing team fully understand the learning objectives behind the story before attempting to refine the story. The GAM is very good at making explicit these learning objectives before the creative process begins and, therefore, demonstrates to everyone what should be achieved in the course of the game. This allowed all the team members to start from a common knowledge point.

The fact that the learning objectives were defined at the act level, and not at the individual scene level, gave the story writers a lot of freedom in that each individual scene could have one or more learning objectives addressed in it. This allowed the design of a more flowing and contextualised environment.



**Figure 3.2** Model showing the thoughts of the designers on the Game Achievement Model. The GAM provides a good framework from which to design the storyline. This good structuring impacts directly on the groups' ability to understand the learning objectives and organise its thoughts which, in turn, facilitate effective puzzle design and placement, easy character definition, a guided creative process and finally the creation of a non-linear storyline.

Essentially in an exploration game of this nature, it is not practical to have a linear story that goes from beginning to end, but rather to have a story where exploration is the key and the player can determine for themselves which route they want to take to reach the end point. Therefore, the use of a linear story is not feasible in such a game. However, writing a non-linear story is complex and difficult. The GAM, with its support structure, allowed the team to work from a linear story in the beginning, and then design a non-linear adventure around the original script. The model was instrumental in enabling the story team to do this.

The open nature of the GAM allowed the team to easily identify different characters within the story and define how the inclusion of these characters would enhance the game and further the learning objectives of the game. The model allowed for descriptions of the actors, their interactions, gestures and dialogue, and helped the team place in perspective what functions they performed within any particular scene or act.

Finally, the inclusion of appropriate puzzles in a game is often difficult. Puzzles can be complex to design and they can often be misplaced in the context of the game. The GAM, because of its good support structure and

transparency, allowed the team to match the puzzles to the learning objectives and ensure the puzzles were appropriately placed within the game.

A potential difficulty with the GAM was that, because of its reductionist framework, some of the members of the storyline design team found the model difficult to conceptualise. This problem was overcome by a process of reiterative review and group social discourse concerning the GAM. Once all members of the storyline design team fully understood the model and the way in which it worked, then the use of the GAM became a valuable part of the storyline design process.

### **3.2 Final storyline**

The final storyline that was decided on for the portal is described below.

Dr. Meisner, after having qualified from a South African University, has moved around the world to various academic institutions around Europe and the Americas, working in the AIDS field. On returning to South Africa, Meisner has established a company (called Syntech) that manufactures anti-retroviral drugs. Frustrated by the long process of Food and Drug Administration (FDA) testing, Meisner has secretly become involved with illegal anti-retroviral testing on humans.

While doing research in institutions where an internship could be done, Carua (a medical intern) hears about Meisner's pioneering work. Carua meets Meisner and manages to convince the doctor to establish a laboratory near Carua's native village in the North African country, Quania. Carua's motive is to return to Quania and help the native people. The outbreak of ailments such as TB and dysentery amongst the Quanian people, heightens Carua's hope that Meisner, with a significant capital contribution and medicines, will be able to better the lives of the people.

Meisner, on the other hand, sees the opportunity to cure their current diseases, win their trust, and subsequently test the anti-retrovirals on the village people. Carua is oblivious to this and believes that Meisner is doing the community a valuable service. Fortunately, HIV hasn't been a problem for the people of Quania as they have been largely isolated from the world. Meisner realises that the healthy people will have to be injected with HIV-positive serum before the anti-retrovirals can be tested on them.

Within the village, Carua's cousin, the village leader, is quickly cured of TB when afforded medical treatment by the doctor. This, along with the influence of the intern, builds the confidence of the villagers in Meisner. Hence Meisner seizes the opportunity to begin the human testing regime under

the auspices of "immunization against further disease". Predictably, the villagers begin to fall ill again. This time, though, the anti-retrovirals do not work as anticipated, and people start to die in numbers. This results in much tension among the villagers, polarized by the village leader (who has pledged allegiance to Meisner and Carua) on the one hand, and the wary, all-seeing and powerful sangoma on the other hand.

The sangoma is the voice of dissent against Meisner in the village and has the power to see through Meisner's façade. The sangoma attempts to convince the villagers of their folly if they choose to follow the doctor.

With the ever-increasing numbers of dead, and in the midst of disease, the villagers are confused as to right and wrong and start to form two different "factions" - one for Meisner, and one against.

The game player enters the game amongst these tensions. The learner arrives in the village unaware of the happenings. Through various educational puzzles, riddles, interactions with the story characters and visual clues, the learner must piece together past events, and possible causes of the rife disease. In so doing, the learner threatens the isolated and illegal dealings of Meisner, and can potentially expose him and bring the testing to a halt.

Further to this storyline, a description of the general portal layout and the content for each area was also negotiated amongst the focus group members. There are six main areas in the portal and these were defined as follows:

The first of these is the burning ground where the dead villagers are burned (under Meisner's instruction). Meisner insists this strategy is to curb the further spread of the disease, but it, in fact, serves to destroy any evidence of drug testing on the victims. Well placed visual clues in this environment provide the learner with clues to the existence of some kind of drug in the village, the company that supplies these drugs and the death of the villagers.

The second area is the field laboratory which is a brick building that contains most of the instruments for disease testing, in particular, those used for testing the blood for HIV and malaria infection. Meisner, however, keeps the results of the HIV testing from Carua and the learner as this would give away the plot. On the walls of the lab are posters showing the structure and infective mechanism of HIV, as well as the life-cycle and infective mechanism of malaria. There is also an ELISA reader, used in testing blood samples for HIV, as well as a puzzle interface showing the malaria life-cycle in the blood of humans.

The third area, which is adjacent to the laboratory, is Dr. Meisner's office. The walls of this office are lined with Dr. Meisner's certificates and qualifications showing the learner that Meisner is well travelled and has much experience in the HIV/AIDS field. On the Doctor's desk is a paperweight model showing the structure of a bacterium, as well as a 3D model of the proposed structure of the HI virus. The Doctor's computer harbours a copy of an email written by Carua to the funders addressing concerns of ill health in the population. This email was modified by Meisner before being sent, such that it contained only positive comments about the project. This serves to heighten suspicion against Meisner in the learner's mind. Inside the desk drawer is the Doctor's personal journal, documenting the death (from cancer) of Meisner's wife.

The fourth area of interaction is the village. This is where the learners meet the village leader and have the opportunity to hear the headman's version of what has been happening. This helps create the tension that supports and motivates the learner through the game. In the village huts, the presence of special candles burning continuously hints at the preventative measures that have been taken, under Meisner's direction, by the villagers to reduce the incidence of malaria in the village. Meisner requires this action to ensure the villagers are initially disease free for improved drug testing.

The sangoma hut is the sixth area of interaction where learners can hear the sangoma's version of the events and it is here that the learners are given a cryptic clue of what needs to be done to resolve the problem in the portal. The sangoma, a mystical and spiritual figure in the village, speaks in riddles and this contributes to the almost mystical, uneasy tension that develops in the portal.

The next area of interaction is the medical tent where all the people subscribed to Meisner's regime of drug testing are kept, especially when they become too sick to live a normal life. This scene contains a big tent with many beds arranged in a dormitory layout, with each bed housing a sick person suffering either from a rare type of cancer, malaria or tuberculosis. In fact, all of them are suffering from AIDS which makes them far more prone to opportunistic infections such as malaria and tuberculosis, to which they are usually immune, but this fact is concealed from the learner and Carua. Mosquito nets are covering every patient in the medical tent and, once again, this is to slow the incidence of malaria in the test subjects.

The final area of exploration is the doctor's private store-room, accessible only by the Doctor. However, by talking to the villagers and exploring all of the different areas whilst learning about different aspects of the above-mentioned diseases, players acquire four picture slides as well as four subunits of a key that, once placed together, allows the player access to the storeroom and access to the secret files kept within. The four parts of this key are embedded in various areas of interest throughout the portal while the four slides are retrieved by learners after solving relevant puzzles. When the learner accesses this room, the files detailing the full testing procedure and the deaths of infected villagers are found. After viewing these files, the learner

can realise fully what has been happening, why the villagers are dying, and why they are succumbing to diseases against which they are normally immune.

The final resolution of the game is when the player manages to report this to the authorities and the regime of illegal and immoral human testing is exposed and ended.

### **3.3 Testing learner opinion of the storyline**

The purpose of the storyline was to invoke sufficient learner interest in the game-playing process so that learners remained interested and would become intrinsically motivated to complete the game. The main purpose of designing the village layout in the manner previously described, was to support the inclusion of appropriate puzzles to facilitate the acquisition of knowledge concerning the main educational objectives. As a consequence of the intended distribution of this game to young South Africans, a large multi-racial and multi-cultural population, the mandate was also given that all the stereotypes in this storyline should be broken, within reason, and that the story itself should be racially neutral and therefore acceptable to all.

To test the effectiveness of this storyline, and to gauge whether it did indeed achieve its objectives, learners at the University of Natal, Durban were polled for their opinions on the storyline.

#### **3.3.1 Storyline questionnaire**

Respondents were chosen from the first and second year groups in the Science faculty at the University of Natal, Durban. This sample structure was selected because of its coherence target age group for the portal. Random stratified sampling was used to select respondents from all major race groups present in this population. Within each race group, individuals were randomly chosen. A small sample of 20 individuals was obtained. Unlike the survey carried out in determining the gaps in knowledge of the learner population at large, this questionnaire was simply for the purpose of eliciting learners' opinions of the storyline, and not an effort to characterise the information needs of a much larger population.

#### *Mixed mode survey*

Self-administered questionnaires are generally cheaper and quicker than face-to-face interview surveys (Babbie, 2001), which makes them preferable when surveying a student population. The unfortunate aspect of these surveys, though, is that they still require a reasonable amount of time to complete meaningfully. When selecting a random sample, it was necessary to request respondents to spend a few minutes filling out the

questionnaire before returning it to the surveyor. This was not always convenient or practical for the respondents as they are usually en route when approached by the surveyor.

With this limitation in mind, the advantages of web technologies, such as active server pages, were considered as a possible mode of delivering these questionnaires to selected respondents. One of the strengths of this method is that respondents could answer the questionnaire when it was convenient to them, allowing the respondents more time to elaborate on their answers and therefore increase the richness of the open-ended questions asked of them. An added advantage is that online surveys have the ability to “force” respondents to answer any questions if the designer deems that question to be crucial to the study (McElroy *et al.*, 2002), resulting in more comprehensive responses to web-based surveys than paper-based surveys. Hence this approach was incorporated into the sampling procedure.

A mixed mode approach was taken with possible respondents being given the choice of answering the paper-based questionnaire there and then at the time of asking, or to furnish the surveyor with their email particulars and then complete the questionnaire form on the Internet at a later, more suitable time. If respondents chose instead to answer the questionnaire at a later time, then an email was sent to them on the same day, containing a link to the appropriate site where they could complete the questionnaire.

According to Babbie (2001), an immediate concern when polling respondents using the Internet is that of representation. He pointed out that not all individuals in the population have access to a computer or the Internet and, although thousands of people may be surveyed in larger projects, this large sample size does not guarantee a representative sample of the population in question. This concern was, however, not a factor in this study as respondents were given the choice of whichever mode they preferred, and respondents would not have specified an Internet-based technology if they did not have access to computer resources. In addition, all students at the University of Natal, Durban have access to various computer local area networks as a matter of university policy.

McElroy and colleagues (2002) performed a comparison of open-ended questionnaires between web-based and pencil survey modes and reported that the web-based survey returned results that clearly surpassed the paper and pencil method. Further, they stated that the number of words, characters, unique concepts and sentences per response were greater in web responses than paper responses. In another study, it was asserted that online web-based surveys had a brighter future than e-mail based surveys and advantages for web-based surveys included low operating costs and very rapid response (Totten, 2003). One possible downfall of this method could be a poor response rate from respondents (Totten, 2003).

Taking all of the above into account, both paper-based and web-based surveys were conducted to elicit the responses of learners at the University of Natal, Durban. Both surveys were constructed with identical questions and wording to remove the possible confounding effect of different survey papers (Appendix B).

### *Survey Analysis*

From a total of twenty respondents, twelve answered by means of the web-based survey, while eight answered paper-based surveys. The responses obtained from both sets of questionnaires were captured into a Microsoft Access Database before being transformed into a more manageable format for graphic display and analysis. Because of the information-rich nature of open-ended questions, common answers across all the responses for each question were grouped using a qualitative data package, NVivo (QSR). The frequencies with which each group occurred in the answer spectrum were then graphed using SPSS (version 11.5).

### **3.3.2 Results and discussion**

#### *Suitability of the Storyline*

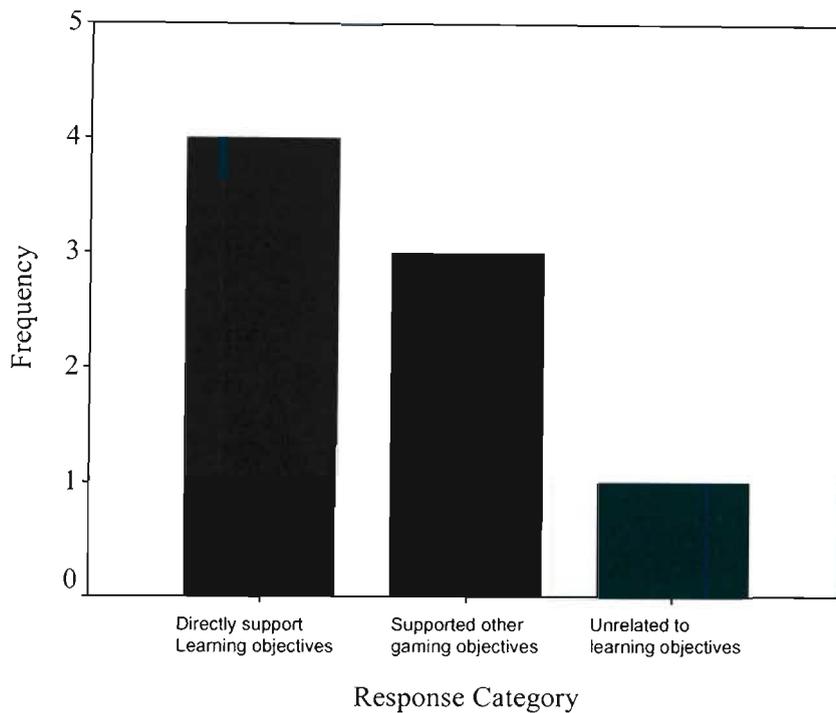
In addition to grouping the answers for question one into various common themes, the themes were further separated into three broad categories constituting:

- (1) answers that related to direct learning objectives of the game (e.g. learning about diseases),
- (2) answers that were related to objectives of the game, but not necessarily the learning objectives per sé (e.g. ethical issues concerning scientific research), and
- (3) answers that were not related to the broad objectives of the game.

The responses for question one are shown in Figure 3.3.

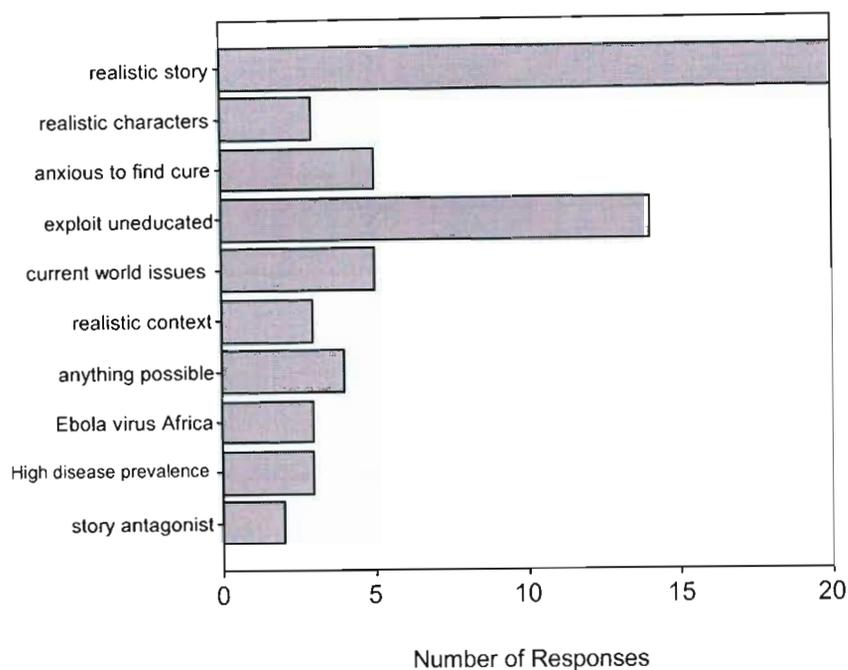
The highest frequency of responses occurred within the category related directly to formal learning objectives of the game. The next highest frequency occurred in the category that described general objectives of navigating in a 3D adventure-game environment, and was followed with the lowest frequency of responses occurring in the category unrelated to any of the gaming objectives. These results demonstrate that the main learning objectives for the game were identifiable by the majority of the respondents and were therefore intuitive and well-linked to the storyline.

When asked whether the respondents found the storyline to be realistic and believable, all respondents answered positively. Furthermore, respondents provided reasons why they found the storyline to be realistic (Figure 3.4). Respondents cited many reasons for considering the storyline to be realistic. These reasons included the fact that poor and uneducated individuals are often exploited by those in power, the fact that the portal concentrates on current world issues, such as the search for a cure for HIV and that the prevalence of these diseases are currently high enough to warrant this type of scenario in the village.

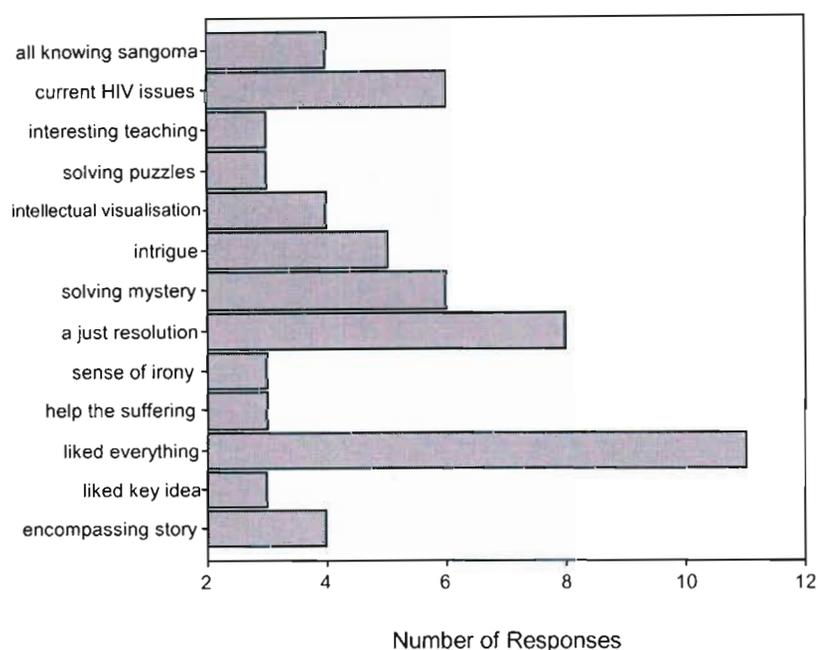


**Figure 3.3:** Figure showing the frequency of categorised responses for all questionnaire respondents. Answers provided by respondents were grouped into three categories depending on whether they directly supported the learning objectives, whether they supported other inclusive activities for the portal or were not related to the learning objectives.

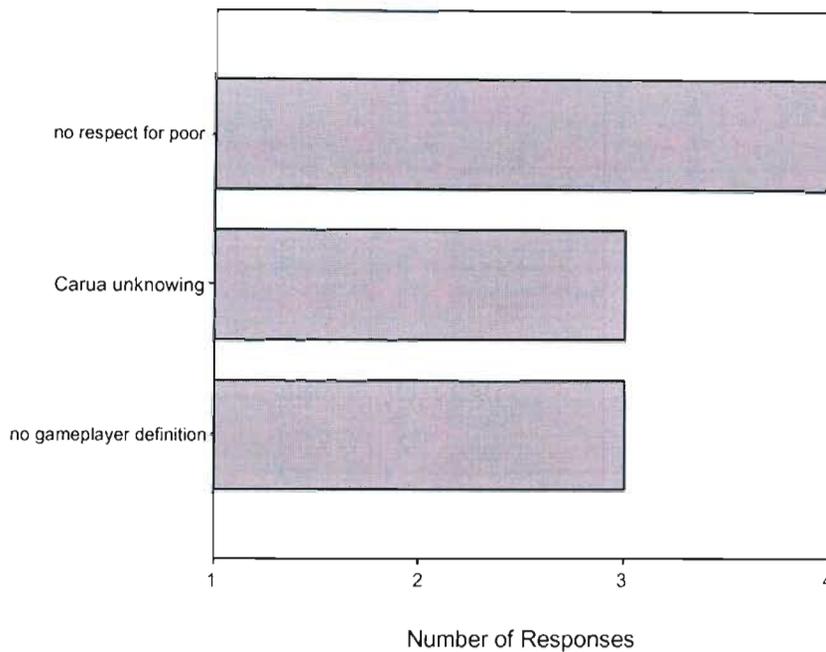
Respondents also reported that a number of different aspects of the story were appealing. Learners enjoyed the intrigue factor of playing a game of this nature, the thrill of solving the mystery, learning about current diseases and the sense of justice provided by the game resolution (Figure 3.5). When questioned about their dislikes concerning the storyline, more than half the respondents contended that they had no dislikes, whilst others cited factors such as the lack of regard by the rich for the poor and uneducated as well as the lack of characterisation of the role of the learner when inside the portal. The fact that Carua was misled and exploited by Dr. Meisner was also disliked by some respondents (Figure 3.6). This is seen as a strength of the storyline as it is this kind of tension that strengthens the resolve of players to persevere and successfully solve the mystery.



**Figure 3.4:** Learner opinions on realism of the storyline. All respondents found the story to be realistic. Reasons cited for the realistic nature of the story included realistic use of characters, realistic exploitation of the villagers and relevance of the storyline to real world referents such as high prevalence of disease.



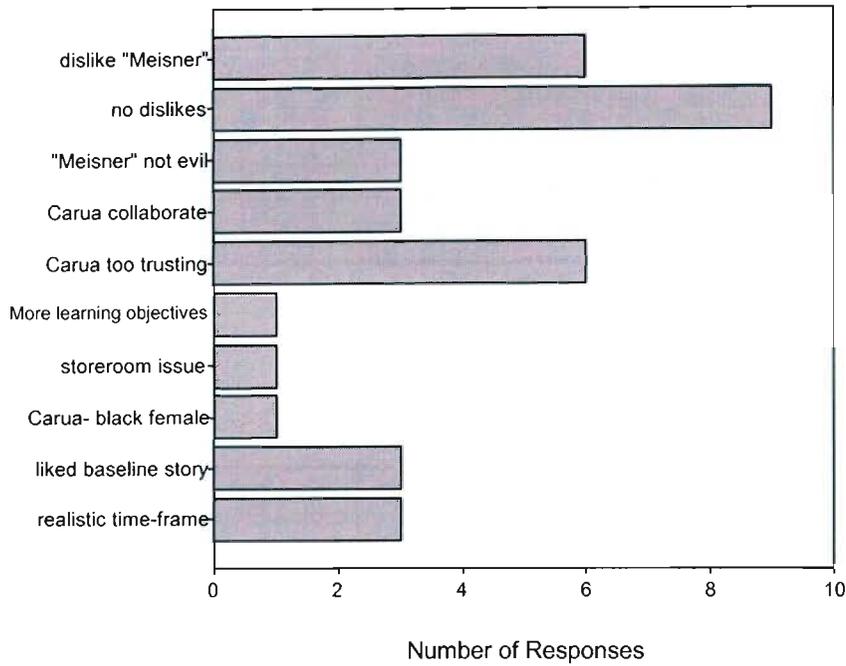
**Figure 3.5** Graph showing what learners liked most about the story. More than half of the learners responded that they liked everything in the story, whilst others mentioned specific areas of the storyline they found favourable. Learners appeared to like the concept of a just resolution at the end of the game, as well as the intrigue of solving a mystery and learning about current HIV issues.



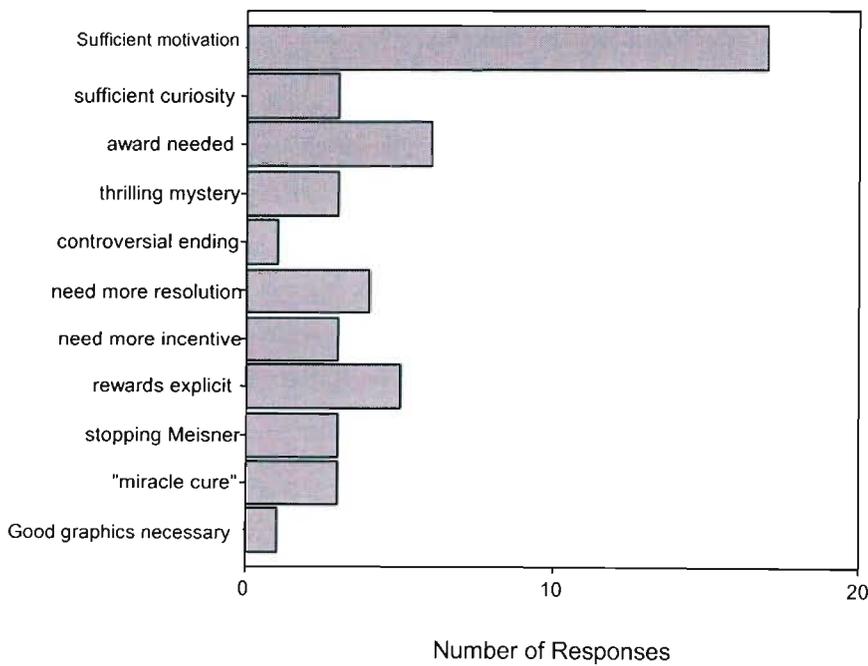
**Figure 3.6** Expression of learners' dislikes for the story. Some learners expressed dislike for the lack of respect shown to uneducated, poor communities whilst others criticised the fact that the role of the learner in the game environment was not well articulated (i.e. why the player was in that environment). Other learners did not like the fact that Carua was an unwitting accomplice in the story. Generally, most learners did not express serious issues with the storyline.

To see if any areas of the storyline could be improved upon, respondents were asked to specify what, if anything, they would change in the storyline if they were given the chance. A number of learners said they would change nothing, but others wanted some of the characters' names changed and wanted Carua to be less trusting. A few learners suggested that Carua assist the learner in exposing Dr. Meisner, and to relinquish the assistants' more passive role (Figure 3.7).

The main aim of the storyline was to provide learners with the incentive to complete the game and want to continue learning from the puzzles within the game. Therefore, learners were asked if they thought a storyline of this nature would hold sufficient interest and resolution at the conclusion of the game to keep them intrinsically motivated. The majority of respondents (85 %) agreed that the current storyline would be sufficient to keep them interested in continued game-play. Some articulated that perhaps a tangible reward, such as a well-known award or medal, at the end of the game would benefit the story and encourage more learners to persevere. The need to make these potential rewards explicit at the beginning of the game was also expressed (Figure 3.8).

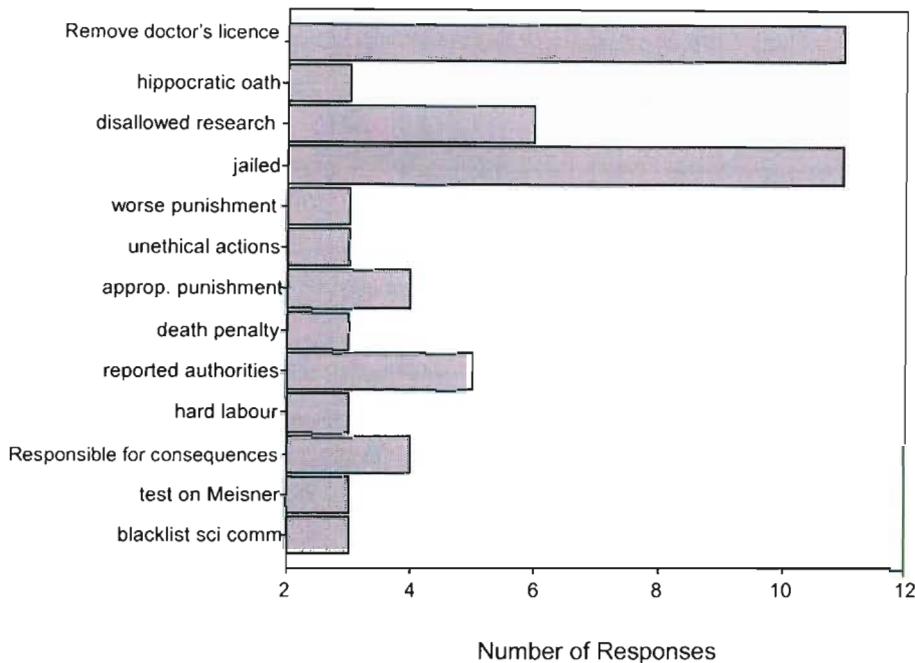


**Figure 3.7:** Learner suggestions of what could be changed in the story. A number of respondents articulated that they did not like the name ‘Meisner’ and some suggested that this name was not evil enough. Some learners felt that Carua was too trusting of Meisner and did not ask enough critical questions. Other learners thought that Carua should have more collaboration with the learner and should actively play a role in exposing Meisner’s activities.



**Figure 3.8** Learners perceptions concerning motivation in the story. The large majority of learners felt that the storyline provided enough motivation to encourage them to complete the game. Learner suggestions included the need for an award or recognition after solving the mystery with this reward being explicitly mentioned at the beginning of the game.

In connection with the game resolution, players were asked what kind of punishment for Dr. Meisner would be appropriate and sufficient to motivate them to complete the game. The majority of respondents expressed the views that Dr. Meisner's medical licence should be revoked from him, his freedom to conduct research should also be removed, and he should either be imprisoned or even given the death penalty. Learner reaction was quite strong in this regard (Figure 3.9).



**Figure 3.9** Learner ideas of adequate punishment for Meisner. Generally learners expressed the need for a harsh form of punishment for Meisner. Included in these proposed sentences were jailing, the death sentence, being reported to the authorities, and being blacklisted from scientific community. Some respondents also suggested that as punishment Meisner should be the subject of his own testing.

Finally, learners were asked if they had ever before participated in an adventure game of this nature. As many as 17 of the learners in the survey had never played such a game before. The three who had played adventure games before, reasoned that they tried to complete these games to achieve goals.

### *Character Analysis*

In this section of the questionnaire learners were asked to, based on the role they would play within the portal, define what demographic groups they saw characters belonging to. Nowhere in the articulation of the story to learners was any reference made to the age, race, gender or physicality of the main characters. These had been pre-defined as a function of the story design process, but the purpose of this section of the questionnaire was

to assess if the designers of the story had been successful in fulfilling the mandate of breaking the stereotype where reasonably possible. In order to do this, respondents were asked to provide details of what they thought the character would be, and these descriptions would then be compared to those of the predefined character descriptions. If a character definition conformed to a stereotypical description, then this stereotype would be expressed by the majority of learners.

All respondents (total of 20) specified that Meisner would be a white male, with a mean age of 43 years (Figure 3.10), depicting well the stereotype that exists for the situation in the storyline. Since, by original definition from the workshop and subsequent focus groups (Appendix C), Meisner is cast as a character of mixed colour, the stereotypical image of the individual in power is broken here. Physical descriptions of Meisner varied somewhat in this sample, but the general theme of Meisner being of large stature was prominent across most answers. This could be a function of the authority and power he is seen to exert in the story. Meisner was also identified as an older, more experienced character and this is consistent with his role in the adventure as well as his original character definition. By definition, though, Meisner is of slighter build and is more of a manipulator than an aggressively forceful character.

Carua was seen as a black person by all respondents and as a female by all but one. All of the learners who categorised Carua as female described this character as being beautiful, young and naive. The respondent who classified Carua as a male described this character as being slightly built with a more reserved appearance. Carua as a young, black naive female medical intern working under the evil white male Doctor was basically the stereotype that most players expressed in their views. This issue of stereotyping was at least partially addressed by casting Carua as a young male intern. It was, however, deemed necessary for Carua to be black to make the story more believable. This was because of the link between Carua and the village through family connections.

Both the village leader and the sangoma were seen as older individuals (Figure 3.10). This is a function of culture as in most cultures, the elders are respected and obeyed, and both these characters were said to command authority within the village. All respondents described these characters as being black. The village leader was also seen as a male leader figure by all respondents, while the sangoma was seen as female by most of the sample. Generally, the sangoma was seen as slightly older than the village leader. The physical descriptions from learners were apt for the character roles, and were largely consistent with the original definition of these two characters.

The results from the story questionnaire indicate that the learners found the story to be well suited to the task of motivating learners to play the adventure game and reach the resolution stage.

Respondents accurately defined objectives that were, if not all directly related to the formal learning objectives, then at least considered important within the gaming environment. Factors such as learning about different diseases, the symptoms of these diseases and the inter-relation between HIV/AIDS and opportunistic infections were all expressed by learners without being explicitly stated in the storyline.

The participants of this study unanimously considered the story to be realistic and cited various reasons for this view. A majority of the replies focussed on issues of realism and the current nature of the story material. A few people even expressed surprise that something like this had not happened before. The learners believed the whole premise of an educated individual exploiting the uneducated and trusting villagers for greedy gain to be a fair reflection on current societal practices.

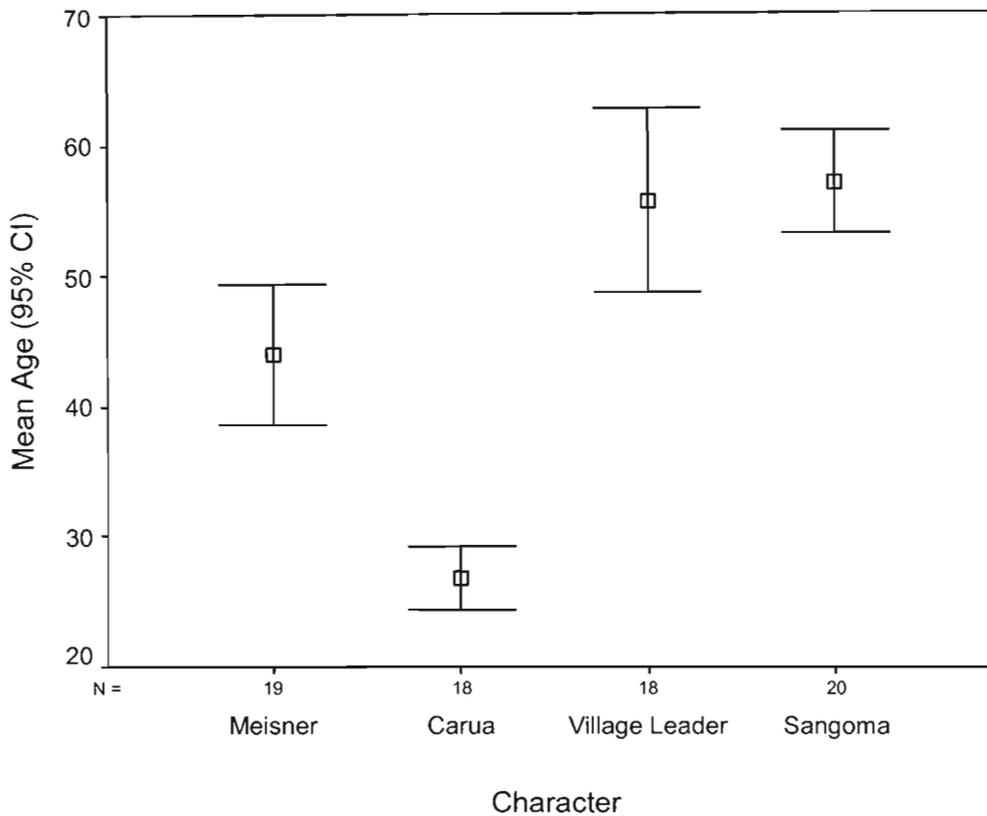
Learners appeared to highly value the sense of adventure that a game of this nature would impart to players. "Solving the mystery" and unravelling puzzles were seen as being strong motivators for game play. In addition, some learners expressed their satisfaction with the way the game made an attempt to address current issues facing this country today.

Potential weaknesses of the story were centred around the interplay between Carua and Dr. Meisner. Learners generally found Carua to be too trusting in the context of what was happening and they expressed the desire to see a more active role from this character in exposing Meisner. Learners also expressed the feeling that a more severe penalty should be imposed for Meisner upon resolution of the game, suggesting the current demise of Meisner to be insufficient.

### **3.4 Conclusion**

The storyline for the game appeared to be well conceptualised in that it provided ample motivation and intrigue for players to want to play the game. As such, it fulfilled its main role in the context of the situated learning environment. The fact that the story was believable provided a realistic context in which the game and educational puzzles were embedded, and could add to the sense of contextualisation for learners. Generally, learners indicated that the storyline was efficient at encompassing and making known the learning objectives for the portal.

The character choices for the portal were realistic and made a conscious effort at breaking the stereotypes inherent in societal thinking. Where elements such as race could not be believably altered, issues of gender were addressed. Judging by learner responses, the character roles were generally well defined and realistic in the context of the game.



**Figure 3.10:** Figure showing the mean ages of the characters as specified by respondents. Meisner is seen as a middle-aged man with Carua being a young, inexperienced and naive woman. Both the sangoma and the village leader are seen as older figures, and this is consistent with cultural structures as they exist in society.

The strength and suitability of the storyline and character definitions could be attributed directly to the social process in which they were defined. This process of social construction and negotiation allowed multiple viewpoints to be accommodated and many issues, not necessarily intuitive in the design of a storyline, to be adequately dealt with. Processes like these are recommended for use in any future situated learning design endeavours.

## CHAPTER 4

### DESIGN OF THE MICROWORLD

#### 4.1 Introduction

As a consequence of our rapidly changing society and constantly evolving information needs, knowledge demands that are being placed on individuals are in a constant state of flux. As a result, our education system is under increasing pressure to undergo change (Laurillard, 2001; Reeves and Hedberg, 2003).

Traditional instruction often fails to promote the transfer of problem-solving skills from one discipline to another because these skills are often taught within contextually sterile, inert environments (Grabinger, 1996; Resnick, 1987). Collins *et al.* (1991) highlight that learners are seldom challenged with relevant 'real-life' problems in traditional instructional settings. It has been argued that this creates a situation where learners consider facts as items that need to be memorized, rather than tools to assist them in solving complex problems (Grabinger, 1996).

Grabinger (1996) furthers this criticism by demonstrating that current educational practices are grounded in five erroneous assumptions (Table 4.1), therefore making them largely ineffective when concerned with authentic learning tasks (Reeves and Hedberg, 2003; Herrington, Reeves, Oliver and Woo, 2004). Instructivist modes of teaching assume that learning abstract and decontextualised information allows learners to easily and intuitively apply this information to a variety of different situations (Choi and Hannafin, 1995). Furthermore, instructivism promotes the use of didactic teaching modes where learners are viewed as receptacles of knowledge and their teachers: the experts responsible for the transfer of knowledge from teacher to learner.

Concern has been expressed over the state of learning in higher educational institutions (Koschmann *et al.*, 1994; Greening, 1998). These authors argue that despite the institutions having set specific goals to impart necessary skills and knowledge to their learners, these goals are not being achieved. Since traditional instruction is often delivered at an unreasonably fast pace, possible reasons for this short-fall include oversimplification of course-work and a lack of reflection time afforded to learners (Koschmann *et al.*, 1994).

**Table 4.1** Instructivist and Constructivist assumptions about learning.

Instructivist Assumptions	Constructivist Assumptions
1. People transfer learning with ease by learning abstract and decontextualised concepts.	1. People transfer learning with difficulty needing both content and context learning.
2. Learners are receivers of knowledge.	2. Learners are active constructors of knowledge.
3. Learning is behaviouristic and involves the strengthening of stimulus and response.	3. Learning is cognitive and in a constant state of growth and evolution.
4. Learners are blank slates ready to be filled with knowledge.	4. Learners bring their own needs and experiences to learning situations.
5. Skills and knowledge are best acquired independent of context	5. Skills and knowledge are best acquired within realistic contexts.
	6. Assessment must take more holistic and realistic forms.

Taken from: Grabinger (1996); p. 667.

In this chapter, the use of contextualised knowledge in situated learning environments will be discussed as a possible solution to the problems of inert information presentation characteristic of instructivist teaching. The importance of problem-based learning will be highlighted and the benefits of the inclusion of puzzles in contextualised learning environments will be explored. The methodologies employed in the design of this learning environment will be described, including the challenges faced in the design of complex 3D environments, character design and scripting and, most importantly, the model devised for the creation and implementation of complex 3D puzzle interfaces. In particular, the constructivist underpinnings of this model, and how these underpinnings translate directly into the model design, will be discussed.

#### 4.1.1 Contextualised knowledge

Bransford *et al.* (1992) contend that knowledge is stored with, and linked to, the situations in which we encounter that knowledge. As a result, learners will readily use knowledge in the context in which it was first acquired. Grabinger (1996) states that the more closely the learning context resembles the actual context, the better learners will perform. Conversely, learners who have obtained knowledge in a decontextualised manner are often unaware that they have the tools necessary to solve a problem (Bransford *et al.*, 1992). Research shows that knowledge derived in this decontextualised manner remains inert (Cognition and Technology Group at Vanderbilt, 1993) and is not readily available for use in novel situations.

#### **4.1.2 Rich environments for active learning**

Grabinger (1996) defines Rich Environments for Active Learning (REALs) as environments evolved from constructivist philosophies which promote investigation within authentic and meaningful contexts, cultivate cooperative learning amongst participants, encourage learner growth and promote high-level thinking processes. These environments promote student-centred learning and place emphasis on intentional learning (Bereiter and Scardamalia, 1989) and the learning of lifelong skills (Grabinger, 1996).

#### **4.1.3 Virtual reality environments**

Virtual reality can be defined as a situated computer environment wherein the user feels immersed (Jacobson, 1993). This environment can be used as a tool for building models, solving problems (McLellan, 1996) and potentially for experiential learning (McLellan, 1996). Hence, virtual reality could be a very powerful educational tool for constructivist learning (Bricken and Byrne, 1993). The sense of presence or immersion is a critical feature distinguishing virtual reality from other types of computer applications (McLellan, 1996), and this immersion can be used effectively in the design of truly contextualised learning environments.

### **4.2 The portal concept**

The scope of this study was to research and design a situated learning environment microworld, or 'portal' as it was termed for this project. The portal was named "In the Service of Humanity" and its subject domain was to address epidemics or prevalent diseases important in the African context and, more specifically, in the South African context. The role of South Africans in the struggle against these diseases, and their contribution to the knowledge base concerning these diseases, was also to be included. This would highlight the fact that South African science and technology is dynamic and part of the global knowledge (Amory, 2000).

Amory (2003) argued that these virtual environments consist of three aspects: an appropriate storyline, integrated problems and technology to support the story and puzzle realisation. This portal was therefore designed as an environment in which learners could immerse themselves and construct their own knowledge about such epidemics while striving to solve an ultimate mystery driven by an exciting and contextualised storyline. The portal subscribes to a constructivist learning approach and provides young South Africans with domain specific knowledge, the cognitive tools as well as an immersive environment necessary to encourage these learners to construct their own views of each knowledge domain. The diseases dealt with in this portal are HIV/AIDS, malaria, tuberculosis and cancer. In particular, aspects of transmission, causative organisms and prevention of each of these diseases are addressed.

The methods with which a situated learning environment was created, as well as those methods used in the design of the puzzles, will be described. In addition, both the graphical realisation and the theoretical background to the puzzles situated in this learning environment will be addressed. The role of the Game Achievement Model in these design processes will also be discussed and any shortfalls or strengths pertaining to this part of the study elucidated.

### **4.3 Portal environment design**

Five main exploration areas were created for this portal, namely the burning ground, the laboratory complex, the medical tents, the village and the sangoma area (see individual area explanations in chapter 3). When planning the portal, various factors had to be taken into consideration, such as the lighting and mood of the portal environment and the type of environment to be created. The portal environment was designed to emulate a remote location in a Central African country and was, therefore, set in an equatorial forest belt.

#### **4.3.1 Three dimensional (3D) world construction**

Three dimensional art creation is a complex process and requires a considerable time investment before any level of proficiency is achieved. The basic principle of this art form is that all physical objects are made up of three dimensional component shapes. Take, for example, a table. Since the software that the designer uses is capable of generating primarily basic shapes (e.g. squares, rectangles, cylinders, spheres etc.), every object is created from the conglomeration of different basic shapes. Therefore, when building this object, the designer would break the table into its separate component parts (i.e. a rectangle would be used for the table surface and four cylinders would be used for the table legs) and create each of these separately, before then placing all the component parts together to make the final object. The main complexity emerges where the basic shapes that are created need to be refined, for example by chamfering the edges of the table since perfect ninety-degree edges are not realistic and seldom ever occur in real-life objects. When all the surfaces of the object have been appropriately modified to look realistic, then the object is 'textured'. In this process, an image, or texture map, is applied to the object. This is synonymous with wrapping the existing shapes in a form of wrapping paper displaying a realistic texture. In the case of the table, a wood texture may be used. When applying a texture to an object, it becomes necessary to specify exactly how the texture would fit over the object, and this is the process of mapping the coordinates onto the object. This is an important part of the design process because basic texture maps are stretched in particular ways to find the 'best fit' possible for the object onto which they are being projected. For example, a wood texture applied to a sphere looks very different to the same wood texture applied to a rectangle. Once all the component parts have been created, modified, grouped together and textured, the object is complete and ready to be placed into a 3D scene. Once

in the scene, the table is made to look even more realistic by adjustment of the lighting for that scene. The importance of lighting in this task is paramount, and can be an exceptionally important factor in achieving realism within a scene.

The software used in the creation of the 3D environments was 3D Studio Max (Discreet), an industry standard for 3D art design. This software is extremely powerful and flexible and, accordingly, has an incredibly complex user interface. Mastering even the most basic techniques is a time-consuming process and there is a considerable learning curve, and corresponding time investment, when becoming familiar with this software. As a consequence, the entire portal environment shown in this dissertation took approximately twenty months to complete.

When designing this environment two different methodologies were utilised, namely the creation of external environments (burning ground, village, sangoma area and the linking 'passages' between the different areas) and the creation of indoor environments (doctors office, laboratory, store-room and medical tent).

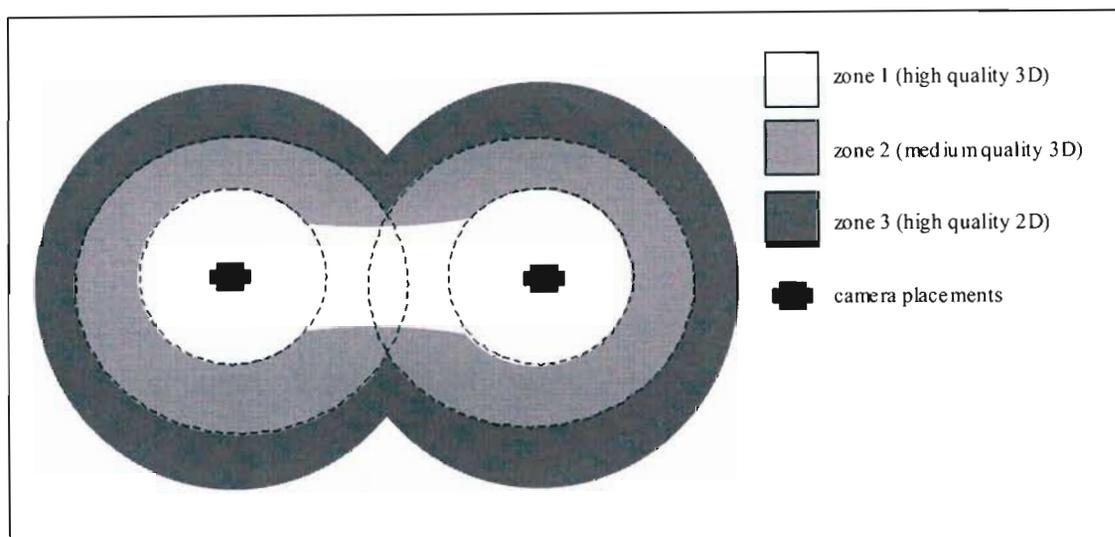
#### *Outdoor environment design*

The methodology for the design of external environments was preoccupied mostly with the illusion of depth. Because of the location of this portal, the depth of field concept referred predominantly to the placement of tree models within the environment to imitate large areas of forest. This preoccupation proved problematic because of the sheer numbers of 3D items required to create depth of field in any given scene. The resource intensive nature of 3D design further complicated this issue in that only a fairly small number of 3D objects could be included into each scene to restrict the file processing requirements to manageable levels.

This conflict between the need for large numbers of 3D models and limited processing power called for a novel solution to this otherwise debilitating problem. It was decided to take the approach where the distance of an object from the camera source would determine the quality of that object. In other words, objects that were situated closer to the camera source were of higher quality than those further from the camera source. High quality models, defined as those with intricate detail (a high number of polygon surfaces used in the model) and high quality textures (large image size and good clarity) were placed closest to the camera source while medium quality models, those containing less detail and often lower quality texturing, were placed at an intermediate distance from the camera source. Finally, two dimensional images (sprites) were positioned furthest from the camera source and were often the basis for the background forestry scenery. While two-dimensional images were generally of high quality and detail, these could not be positioned too close to the

camera because of their 2D nature. This strategy of selective placement resulted in the formation of three different zones of quality for each external environment (Figure 4.1).

Two-dimensional images that were displayed in zone 3 were oriented at approximately  $90^\circ$  to the camera viewport, thereby making it less obvious that the image was not three-dimensional. When 2D objects were placed equidistant from two camera locations, the position best approximating an incident angle of  $90^\circ$  to each camera was used. When this technique yielded unsatisfactory results, 3D models in zones one and two were positioned in such a way as to mask these more distant sprites. Whilst effective in the design of these environments, this strategy was complex to administer when more than two camera points were present in any scene.



**Figure 4.1** Demarcation of concentric zones of quality around camera placements. The reduction of 3D model quality with increasing distance from the camera resulted in the formation of concentric rings of model quality around each camera position (- - -). When one or more camera positions appeared in an environment, the effective combination of these concentric rings resulted in zones 1, 2 and 3, zones of differing model quality.

In addition to model quality and file size, other logistical considerations applied in the design of these environments. Whilst all the models had to be constructed according to scale, the scale used needed to be much larger than was intuitive. Because of the high distortion inherent in the wide angle camera 'lens' necessary for capturing images of this 3D environment, coupled with the resultant stretching of images to cover irregular surfaces, blurring often resulted from a camera picture being positioned too close to an irregular surface. Blurring of this nature would be unsightly and would, to a large degree, defeat the illusion of realism. This lesson was learned in the initial creation of the burning ground and necessary steps to counteract this effect were taken in the burning ground redesign and all subsequent creation of external environments.

Because of file size limitations inherent in 3D Studio Max each of the main constituent areas of the portal were separated into individual files. This allowed tree and grass models to be added successfully to each area to achieve a degree of realism while still maintaining a feasible file size with which to work.

### *Indoor environment design*

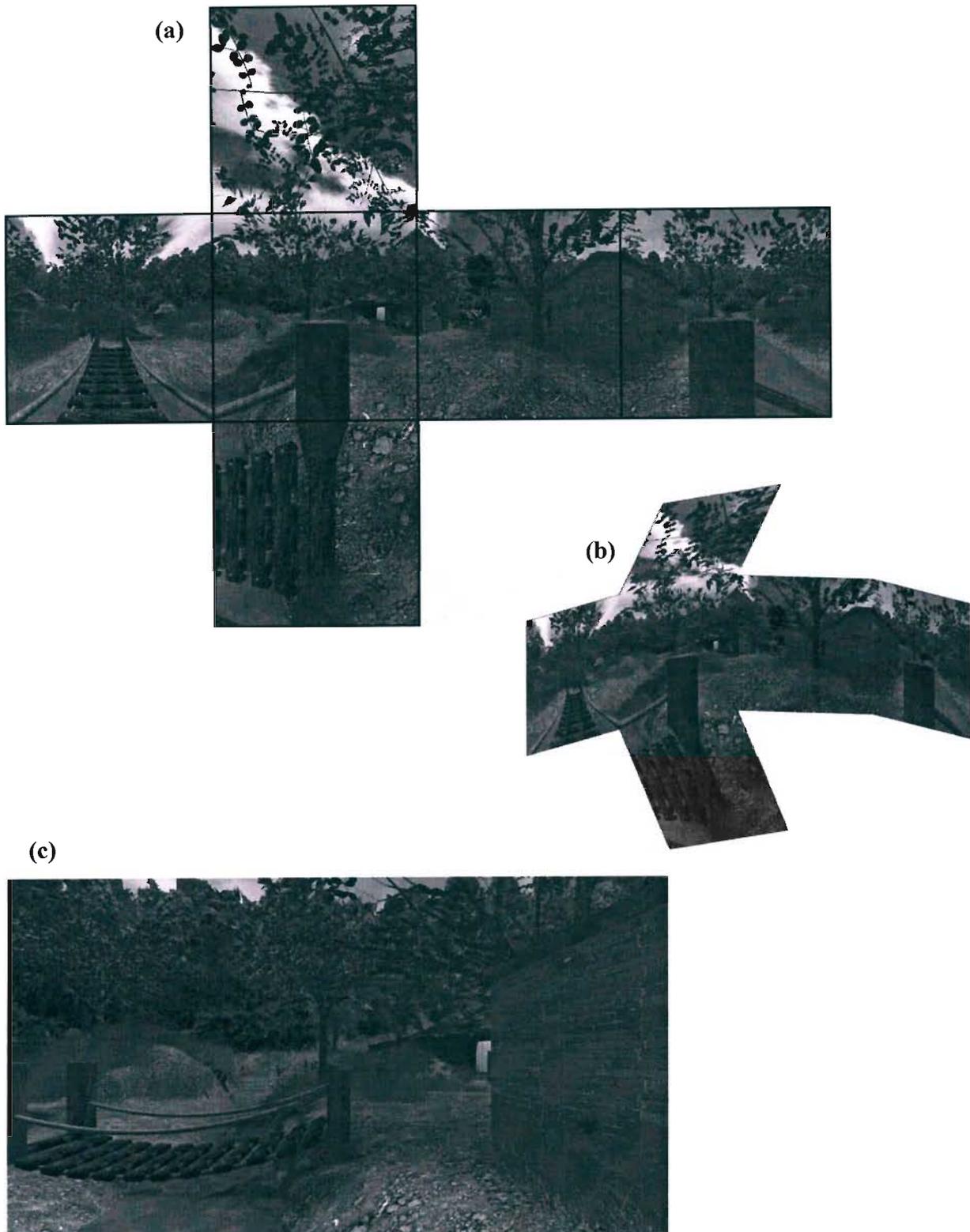
The design of indoor environments does not face the same magnitude of challenge as does the design of external environments. This is because depth of field is not as much of a concern because of the closed nature of internal environments. In other words, each room is enclosed by walls and nothing need be designed and included beyond these walls for any given room. The rule definitely applies that whatever the learner cannot see directly in this environment would serve no purpose in the game, and therefore need not be created.

The appropriate use of lighting in a scene is an extremely powerful tool that can be used to seamlessly convey a message and set the tone for that scene. A corollary of this use of lighting in a scene is the use of shadows. These shadows and highlights can also be used to emphasise important objects or set the mood within a scene.

### *Creating the 3D immersive environment*

Once the 3D environment had been created using 3D Studio Max, it became necessary to take 'snapshots' of the 3D environment contained in this development and transfer them into the game engine, the software package responsible for the running of the game environment. Using 3D Studio Max, cameras were placed into key positions throughout the 3D environment. Key camera positions were defined as those positions allowing access to an object of interest, or positions necessary to facilitate player transit from one area to another. For each camera position (referred to as a 'node') six individual pictures were rendered, namely top-, bottom-, north-, south-, east- and west-facing views. Each of these images had a 90° field of view. When these images were arranged end to end in a structured order (Figure 4.2a) they collectively represented the entire view across all angles for that camera position.

In order to create the 3D environment within the game engine that would be used to run the game, these six images were placed onto the inside of a 'skybox'. A skybox is a 3D cube, whose inside surfaces are textured with the six different views resultant from the rendering procedure discussed above (Bell, 1998). To avoid seeing the joins between the different images or the distortion of images in the corners of the cube, a complex mathematical procedure was applied to these images, stretching them as necessary to make the transition from one image to its neighbour seamless. The learner is placed at the centre of this skybox, giving them the illusion of being immersed in a 3D surround environment (Figure 4.2b).

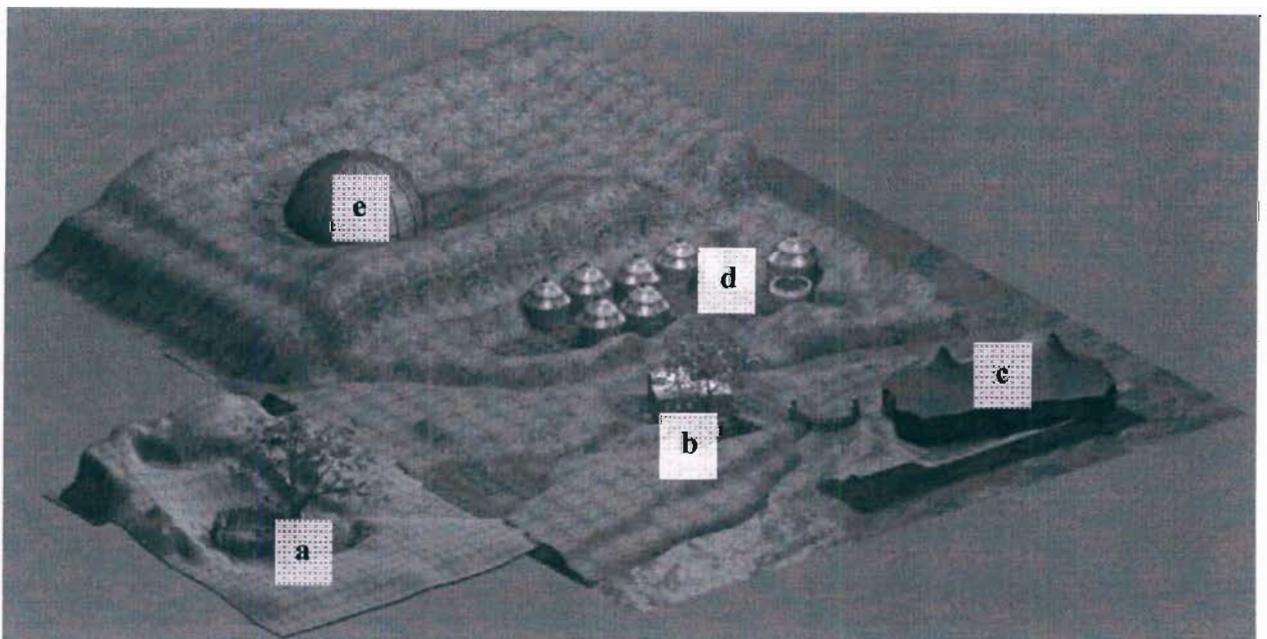


**Figure 4.2** Combination of six rendered images for the production of 3D surround skyboxes. (a) The different views are joined together with each view labelled with the appropriate orientation. (b) Figure showing a 3D cube being unravelled, showing the six views on the inner surface of the cube. (c) A single landscape picture of the environment showing a first-person learner's view of the environment.

For the purposes of describing each of the main portal areas created, the image format in Figure 4.2c is used when describing environment design in the remainder of this chapter.

### 4.3.2 Portal areas

All the areas for the portal have been created and are fully explorable on the  $\gamma$ Khozi CD (located in the CD sleeve at the back of this dissertation). The portal areas comprise of the burning ground, doctor's office, laboratory, store-room, medical tent, village, sangoma hut and the area immediately external to the laboratory complex (Figure 4.3). A brief description of each of these environments will be given as well as an account of the major design mechanisms used in each scene.



**Figure 4.3** The linkage between all the different areas of the portal can be seen in this elevated view of the 3D portal environment. For the purpose of making this illustration the majority of the foliage and forest had to be excluded to keep the file size to a manageable level. The following areas can be seen in this figure: (a) The burning ground, (b) the laboratory complex incorporating the doctor's office, storeroom and laboratory, (c) the medical tent, (d) the village and (e) the sangoma hut.

#### *Outdoor environments*

When the learners first enter the portal they do so through the burning ground area. The burning ground area consists of a higher forested area where the player's movement originates before moving into a flatter low-lying area which contains a type of burnt out fireplace (Figure 4.4a). The burning ground was designed in this way so that when learners first arrive in the portal they can see bits of the fireplace from a distance. Once

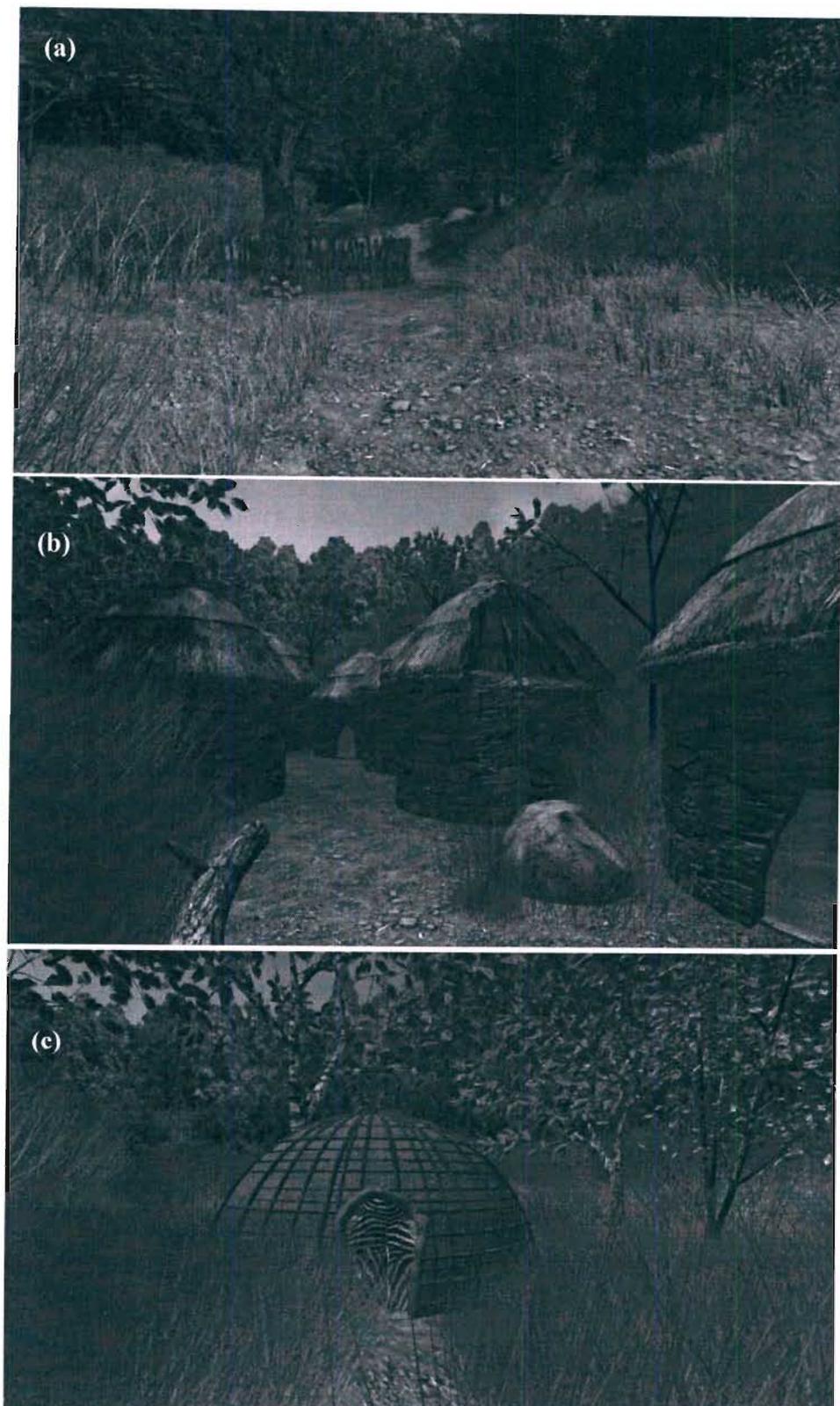
intrigued as to what lies below, the environment leads the learner into the fireplace area so they can explore. The main function of this burning ground area is to alert the learner to the presence of death in the village. When the burning area is explored, the game player will find a burnt out fireplace in the centre of this clearing, and the remnants of burnt items lying on the periphery of the fire place (burnt vial, burnt skeleton and a piece of half burnt jewellery). The player can also find an old tree off to the edge of the clearing wherein many notches have been etched into the trunk of the tree. The number of notches relates to the number of deaths in the village. The purpose of all of these design considerations is to add to the feeling of unease and dark undercurrents in the portal. This scene is therefore essential for setting the mood for the game.

Figure 4.2c shows the connecting corridor between the laboratory complex, the medical tent, village and sangoma area. This area is the most central point of the portal and hence it houses the laboratory complex where most of the educational puzzles are situated. The corridor is flanked by water on both sides and provides learners with access to two foot-bridges that cross the river. The first foot-bridge leads learners to the village and sangoma areas, while the second bridge leads learners to the medical tent. Because this tent is where Meisner's testing is occurring, and where his sick patients are housed, access to the medical tent is guarded from the learner. To gain access to this area, learners must first solve a puzzle which opens the gate connecting the medical tent and corridor areas.

The village (Figure 4.4b) was designed to sit in a protected valley alongside the stream, not unlike the placement of a real village might be. The environment was also designed so that learners could see the village from the lab complex and the medical tent to emphasise to them that there were numerous areas that could be explored, otherwise learners may become frustrated and think that they have explored all possible areas. The interaction with the village headman was also situated in the furthestmost village hut to encourage learners to explore and to feel completely immersed in the village once they were surrounded by the huts.

The sangoma area (Figure 4.4c) was eventually made to be free-standing above the village. Originally it was designed as part of the village but it was felt that this placement would not afford the sangoma the mysterious air that was needed for her character. Therefore, a larger hut, uniquely distinguishable, was situated on higher ground above the village. This served to seclude the sangoma hut and also created a more isolated scene where through the use of music and visuals a mystical feel could be attained.

The strategy of using differential model quality depending on the distance of the model from the camera was employed for all these environments. Accordingly, trees in the foreground are 3D tree models while general foliage visible in the background is composed of 2D images of forest and shrub.



**Figure 4.4** Three remaining external environments created for the portal: (a) Burning ground area where learners first enter the portal (b) Village area where the villagers in the portal live (c) Sangoma area where the sangomas hut is situated.

### *Indoor environments*

The store-room is dark and menacing as this is the area where Meisner's most protected secrets are stored (Figure 4.5a). The feel for this room was achieved through the use of low-level lighting and accentuated shadows. Areas of interest, such as the testing chart on the wall have been lit by low-level down-lights while sunlight pours in the window. The burglar guards on the window stress the fact that the information in this room is well guarded, and the use of sunlight streaming in through the same window casts shadows on the floor. These elements combine to accentuate the feeling of incarceration, secrecy and isolation.

In the same way, the use of low-level lighting in the doctor's office imparts one with the feeling that there is something suspicious in this area (Figure 4.5b). This room, associated with Dr Meisner, contains information that should arouse the learner's suspicions when discovered. The light streaming in through the window also highlights important information relevant to the solution of a puzzle within this environment.

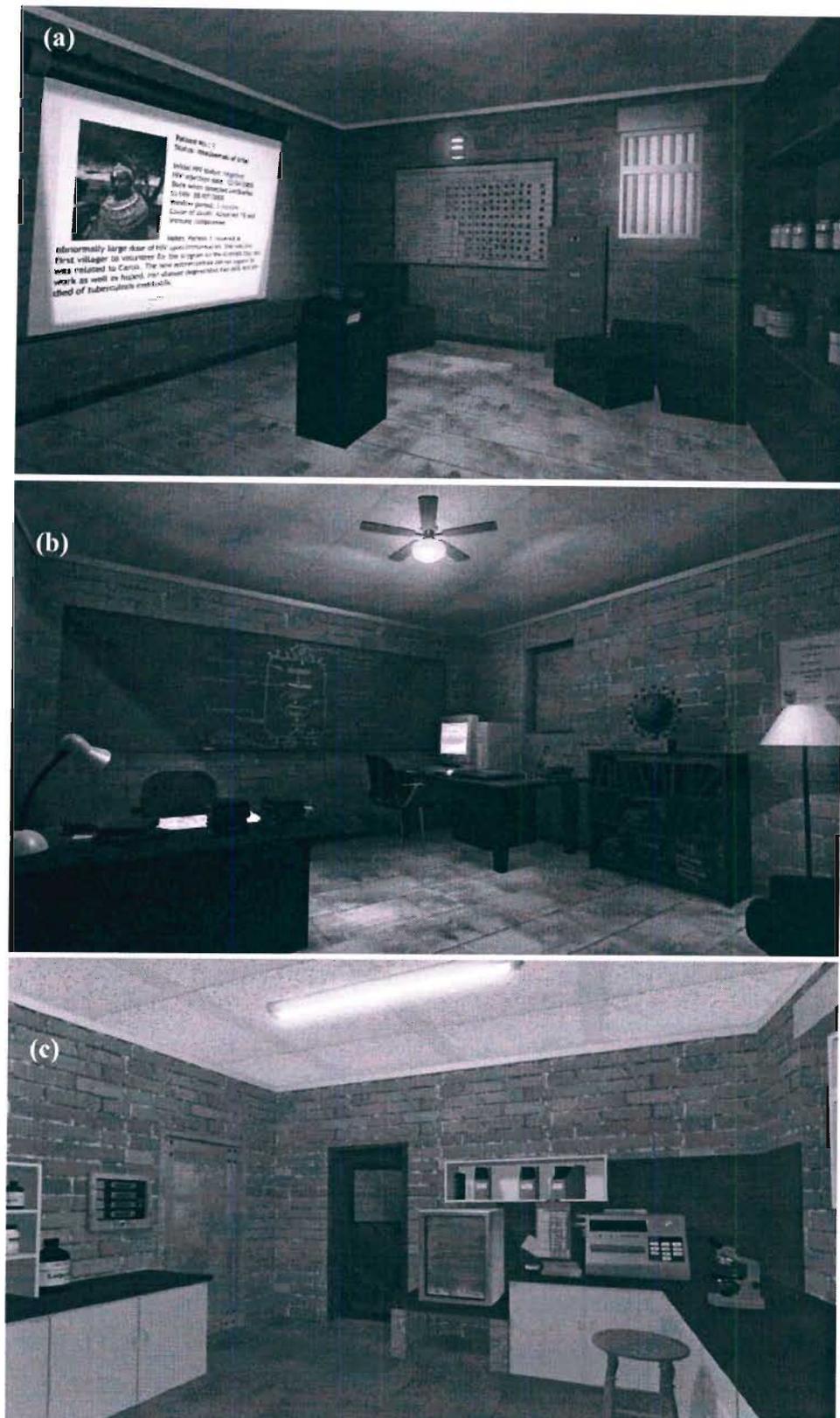
The laboratory has a much higher light intensity than the previous two areas (Figure 4.5c). This use of lighting served to emphasise the clean and sterile environment. The lighting in this instance is used to emphasise the running of a scientific experiment in amongst the disease and suffering evident in the portal.

## **4.4 Virtual character design**

An intricate part of the portal's storyline is the learner's interaction with the game characters. These characters provide a tension within the portal that should get the learners thinking that not everything is not as it seems. This is primarily achieved through the use of conflicting accounts of what is happening within the portal environment.

### **4.4.1 Character situation in the portal**

The way in which the characters have been embedded in the portal is through the use of 'memories' or 'flashbacks'. What this means is that the characters are never actually visible when the learner enters a scene. Instead, there are objects which have been placed in each scene where a character interaction takes place and once these objects are clicked on by the learners a pre-scripted character interaction takes place in the learners field of view.



**Figure 4.5** Figure showing the indoor areas that have been created, namely (a) store-room, (b) doctor's office, and (c) the laboratory. The use of different lighting techniques in these environments gives each environment a unique look and feel.

Originally the characters were designed to interact directly with the learners using the Microsoft text-to-speech engine to simulate a conversation, while the content of the discussion would come from a backend AIML (Artificial Intelligence Markup Language) driven artificial intelligence engine called ALICE (Artificial Linguistic Computer Entity). After iterative character testing it was decided that the pre-scripted pre-rendered character interaction would build a far better sense of the story into the portal. In addition, the original method of character interaction in the portal took place within a popup window which completely broke the illusion of being immersed in a realistic environment. The use of pre-rendered character interactions also meant that now characters could have a dialogue with one another whereas before this was not possible.

#### **4.4.2 Building the virtual characters**

A 3D modeling program called Poser (Curious Labs) was used to build the basic body shapes of the virtual characters. The faces of each of these models were then modified until a desirable look had been achieved. In many cases digital images of people involved with the project were taken and the character features were based on these images. The more realistic the facial texture, the more realistic and convincing the character appeared in the game.

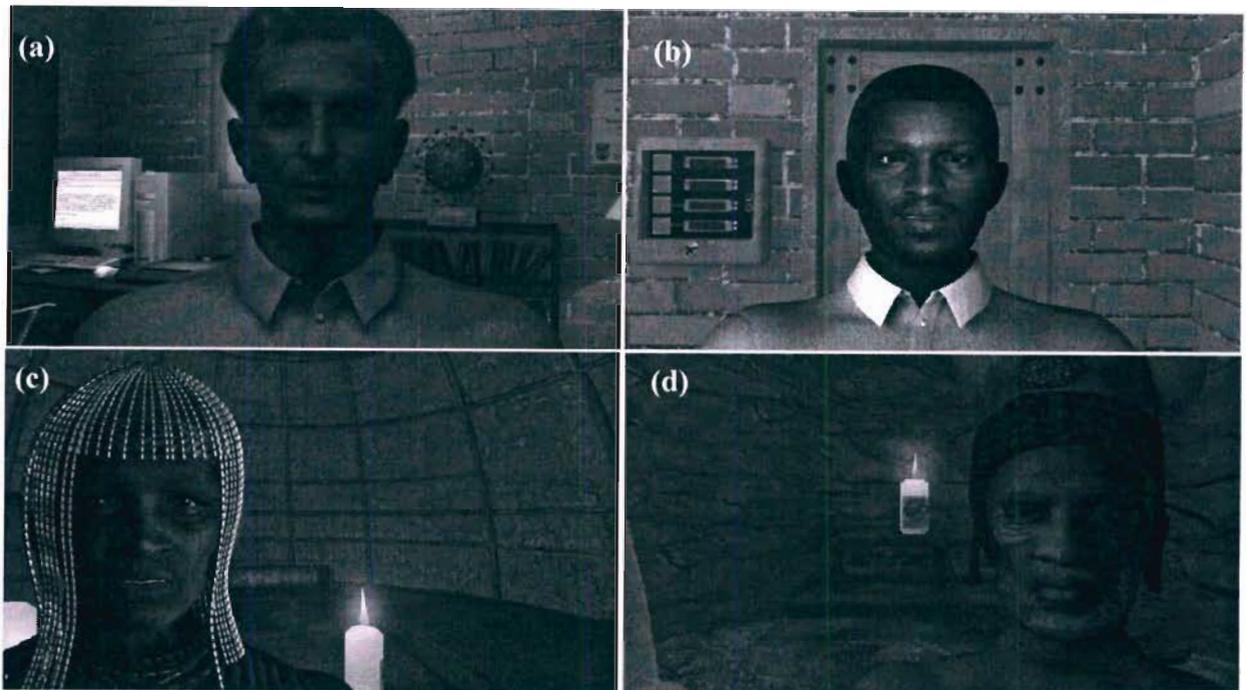
One of the character models, Dr. Meisner, was created by a graphic designer working in the Virtual Learning Spaces Project, Mr David Baxter, but all other characters were designed as part of the scope of this dissertation.

#### **4.4.3 Finding the character voices**

The next step in making the character animations was to adapt the original script for the storyline (written as a collaborative piece by Tasmin Raynor, John van der Ruit and Rob Seagram) and select character interactions from the storyline before adapting these scripts to fit in with the latest portal concept. Once this was completed, a number of members involved in the Virtual Learning Spaces project and a few volunteers and invited guests recorded the script interactions in the Audio Visual sound studio at the University of KwaZulu-Natal.

Once these voices were recorded, the background noise was removed from the files and these audio files were spliced into more manageable segments of audio. Using a program called Mimic (LipsInc) in conjunction with Poser the character models were animated with the speech. In order to make the characters appear as if they were situated in the environments in which their interactions would take place, their animations were

rendered against a background taken from the scene in which their interaction would be played. In Figure 4.6 the final character models are seen situated in the area where they interact with the learner.



**Figure 4.6** The virtual characters for the burning ground portal. (a) Dr Meisner is the head villain in the story while (b) Carua is his medical intern assistant, unaware of the evil deeds Meisner is performing. (c) The sangoma is the all-seeing wise sage and warns the learner of the evil lurking in the village, but the (d) village headman, who is related to Carua, supports Dr Meisner because Meisner cured him of TB.

## 4.5 Puzzle design

Once the different areas of the portal had been created, the puzzles contained in these areas were designed. In this section, the importance of problem-based learning and social construction in the playing of exploration adventure games will be emphasized. Based on the theory, a model detailing the proposed puzzle process to be followed by learners will be introduced. In addition, the manner in which this model was used to design the puzzles is explored and the graphical interfaces, as well as a bit of background for the puzzles, are presented.

### 4.5.1 Problem-based learning

Problem-based learning is a manifestation of REALs (Grabinger, 1996), and can be described as the resultant learning from working toward the understanding or resolution of a problem (Barrows and Tamblyn, 1980).

This type of learning addresses ill-structured problems and ill-structured knowledge domains where resolution of a problem requires more knowledge than is initially available (Wilson and Cole, 1996). Schmidt (1993) asserts that because the activation of prior knowledge is necessary when encountering these problems, problem-based learning is an effective tool for constructing new knowledge from old. The strength of problem-based learning lies in the use of a collaborative environment, the combination of skill and content and the emphasis on student controlled learning (Wilson and Cole, 1996).

Authentic tasks provide realistic learning experiences, important for the ways in which they encourage participants to take ownership of the situation and their own learning (Grabinger, 1996). Because learning also occurs in context, learners have a better chance of forming deeper and richer knowledge structures (Brown *et al.*, 1989; Cognition and Technology Group at Vanderbilt, 1992; Reeves and Hedberg, 2003). Authentic tasks also encourage collaboration and negotiation as some problems are complex and require knowledge transfer between learners (Grabinger, 1996; Reeves and Hedberg, 2003).

#### **4.5.2 Cognitive tools**

Cognitive tools refer to technologies that enhance the power of human cognitive processes such as thinking, problem solving and learning (Jonassen and Reeves, 1996). These tools can be used in problem-based learning because they help learners organize, restructure and represent what they know and should be readily accessible to learners to support reflective thinking within the context of learning (Jonassen and Reeves, 1996). Situated learning environments provide a variety of cognitive tools and resources to support student-centred learning (Tobin and Dawson, 1992), some of which are software programs that use the control capabilities of the computer effectively in enhancing human cognition (Kozma, 1987). Cognitive tools in the computer sense have particular application in situated learning environments. One example of this is the computer's ability to supplement limited learner working memory by making more memory available (Kozma, 1987). In addition, computers can make previously learned, relevant information available at the time of learning, thereby encouraging the formation of associative links and knowledge construction (Kozma, 1987).

#### **4.5.3 Collaboration in the portal**

Learners are encouraged to construct their own knowledge, in part, through the reading of interesting information on a subject domain and subsequent working through a puzzle concerned with that domain. Through a process of social discourse, learners may also collaborate on the issue of solving the puzzle and negotiating shared meanings concerning that knowledge domain. If the learning environment is explored in

conjunction with other learners then this social construction may well be an effective way for the learners to benefit from their interaction with the puzzle interface and their peers.

Ultimately, the final release of the game will also incorporate communication tools which will allow learners to collaborate with other learners who are playing in the environment. This, to a degree, resolves the need for learners to play in groups in the same spatial location, but rather allows for social networking which could extend over great distances. Such communication tools will include a virtual cellular phone and a personal digital assistant (PDA) with internet searching capabilities. These tools will simply serve to increase the dialogic interactions between learners which should help learners negotiate their own socially constructed meaning within the learning environment.

#### **4.6 Puzzle Process model**

To make learning truly successful, learners need to interact with their environment or culture and construct their own knowledge concerning various knowledge domains (Rieber, 1996b). Construction of knowledge in this manner depends on the process of equilibration (Rieber, 1996b). Assimilation and accommodation are two effective mechanisms of equilibration (Rieber, 1996b). Savery and Duffy (1995) affirm that cognitive conflict is the stimulus for learning and determines what is learned. Contradiction in concepts is what causes an imbalance in a learners' view of the world, and it is this imbalance that provides the internal need for accommodation (Fosnot, 1996).

In order to fully understand the process of equilibration, though, it is not useful to think of it as a sequential process of assimilation, followed by conflict and subsequent accommodation, but rather as a dynamic interplay between all these components (Fosnot, 1996). All of these aspects of equilibration should be evident in the initial stages of problem solving when learners encounter the puzzles. In other words, when learners see new material for the first time and make an attempt to accommodate that knowledge into their existing views of that knowledge domain, they should be capable of obtaining at least a degree of new tacit knowledge, in the sense that it has not yet become deep knowledge.

However it is the subsequent reflection on new knowledge that brings about a structural change in the learners' integrated view of the world (Fosnot, 1996). Greening (1998) raises the importance of using technologies to support the reflective process, and in this context, the puzzles provide this technology to learners. Through the cognitive exercise of performing the puzzle tasks and trying to solve the problems at hand, the learner has an opportunity to question and reflect on the new knowledge that has been recently acquired (Boyle, 1997). It is at this stage where learners may be stimulated to reflect on their own thinking

and problem solving skills. This skill is referred to as metacognition and has powerful problem solving potential (Boyle, 1997).

Once a learner has been through the process of acquiring new tacit knowledge, transforming and querying that knowledge through the solving of puzzles, and then reflecting on that knowledge and changing pre-existing knowledge structures, then a learner can be said to have implicit, or deep knowledge concerning that domain. This is the kind of knowledge that is more readily recalled and can be used to generalize beyond the specific experience (Fosnot, 1996).

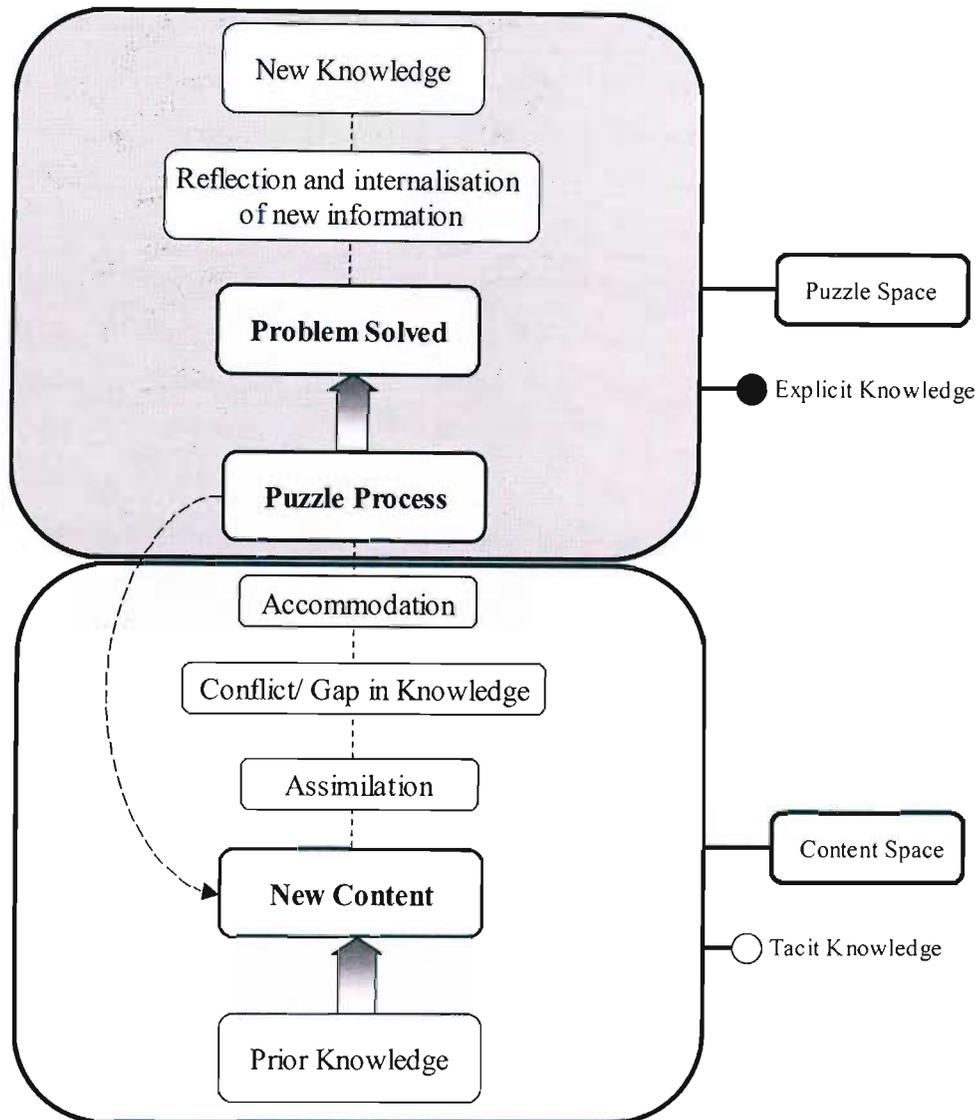
Because the process of design to be followed in the creation of puzzles that support this kind of deep knowledge construction is not defined or documented for these immersive 3D environments, it first became necessary to define the way in which these puzzle interfaces would be created. To this end the Puzzle Process model was defined to guide and inform the creation of puzzle interfaces that would promote implicit knowledge construction.

The Puzzle Process model calls for the creation of two distinct puzzle domains – one to house the body of knowledge that learners would use as a knowledge base from which to operate and transform information (content space), and the other specifically to facilitate the manipulation of that knowledge and to encourage the process of equilibration and reflection (puzzle space) (Figure 4.7). When engaging with a puzzle learners acquire new information in the content space which they constantly match against their pre-existing knowledge structures, entering into an iterative cycle of assimilation, conflict and accommodation. However, it is only through the manipulation of the puzzle interface that learners are given an opportunity to operate on this new information. Positive feedback from the puzzle interface upon resolution of the puzzle further consolidates these concepts in the learners mind. It is after resolution of the puzzle that learners are encouraged to reflect on and internalize this new information. This process of assimilation, accommodation, reflection and internalization results in the formation of new implicit knowledge structures.

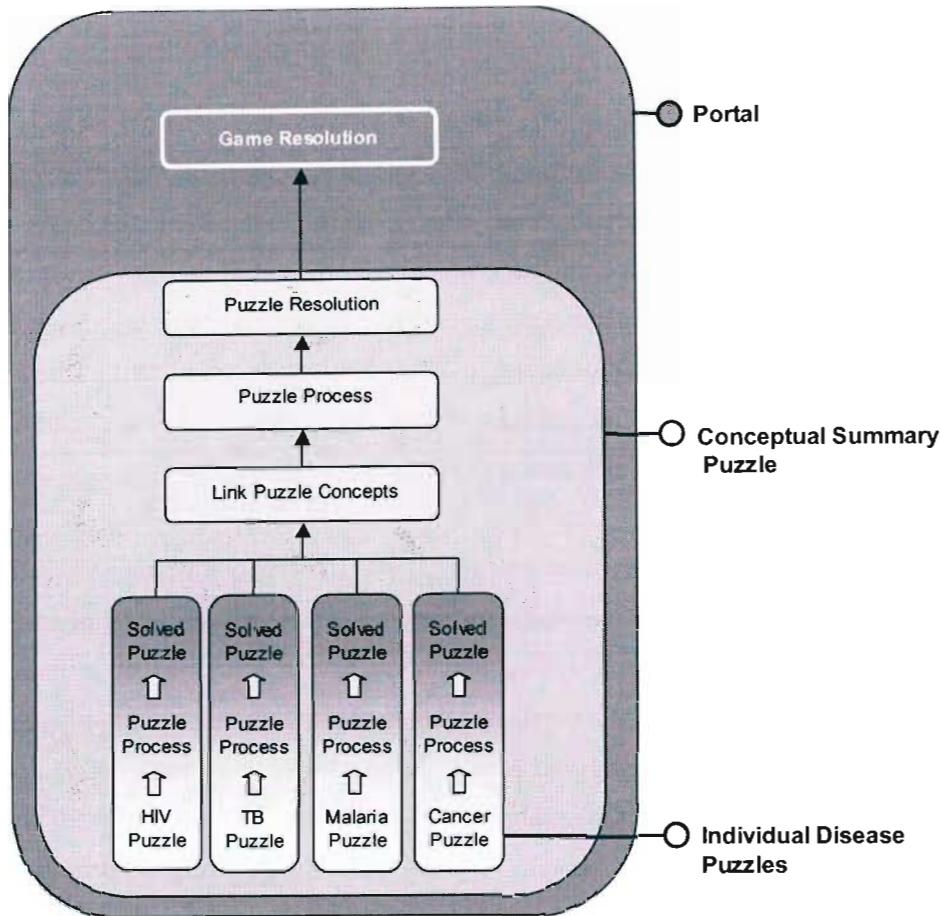
#### **4.7 Puzzle design**

A total of nine puzzles were designed using a 3D graphics program (3D Studio Max, Discreet) and were embedded in the portal virtual environment. The puzzles were not necessarily restricted to one spatial location, but often consisted of a few smaller sub-components distributed throughout the environment. When puzzles were situated in different locations within the portal, both visual and auditory themes were kept consistent for each puzzle to subtly link them and avoid confusion in learners.

The puzzles were also arranged in a low-level hierarchical structure (Figure 4.8) wherein eight puzzles were directly accessible from any previous knowledge base, with the ultimate puzzle being a conceptual summary of the first eight. In that sense, the ultimate puzzle was at a higher level than all eight puzzles encountered beforehand.



**Figure 4.7:** A model of the proposed puzzle process. This model shows the interaction learners should have with the puzzles. Learners acquire information in the content space, while continually matching that information against their pre-existing knowledge structures. Through the process of accommodation, new tacit knowledge is constructed. The puzzle space is where learners use this new tacit knowledge, transform it and solve the puzzle. Once the puzzle has been solved, learners can then reflect on the process and construct their own explicit knowledge concerning these diseases.



**Figure 4.8:** Hierarchical structure of the puzzles. Learners are required to link concepts from the first eight puzzles concerning HIV/AIDS, TB, malaria and cancer before being able to solve the conceptual summary puzzle. Once learners have demonstrated this linking, they are then allowed access to the area where final resolution for the portal is achieved.

#### 4.7.1 HIV/AIDS puzzle

HIV/AIDS is the most threatening, with the most serious long-term repercussions, amongst the four diseases chosen and therefore represented the majority of the puzzle constituent. Three of the puzzles centred around HIV/AIDS, with a fourth incorporating aspects of HIV/AIDS with the other diseases under study here.

##### *Structure of the Human Immunodeficiency Virus and mechanisms of infection in human hosts*

As mentioned previously, one of the main aims of this portal was to introduce learners to the concept of biological agents being responsible for these diseases. In this puzzle, learners should gain an appreciation of

Human Immunodeficiency Virus, the causative organism of AIDS. This puzzle consists of two distinct parts within the doctor's office, one of the portal's spatial locations, and deals with the structure, function and lifecycle of the HI virus in the human body.

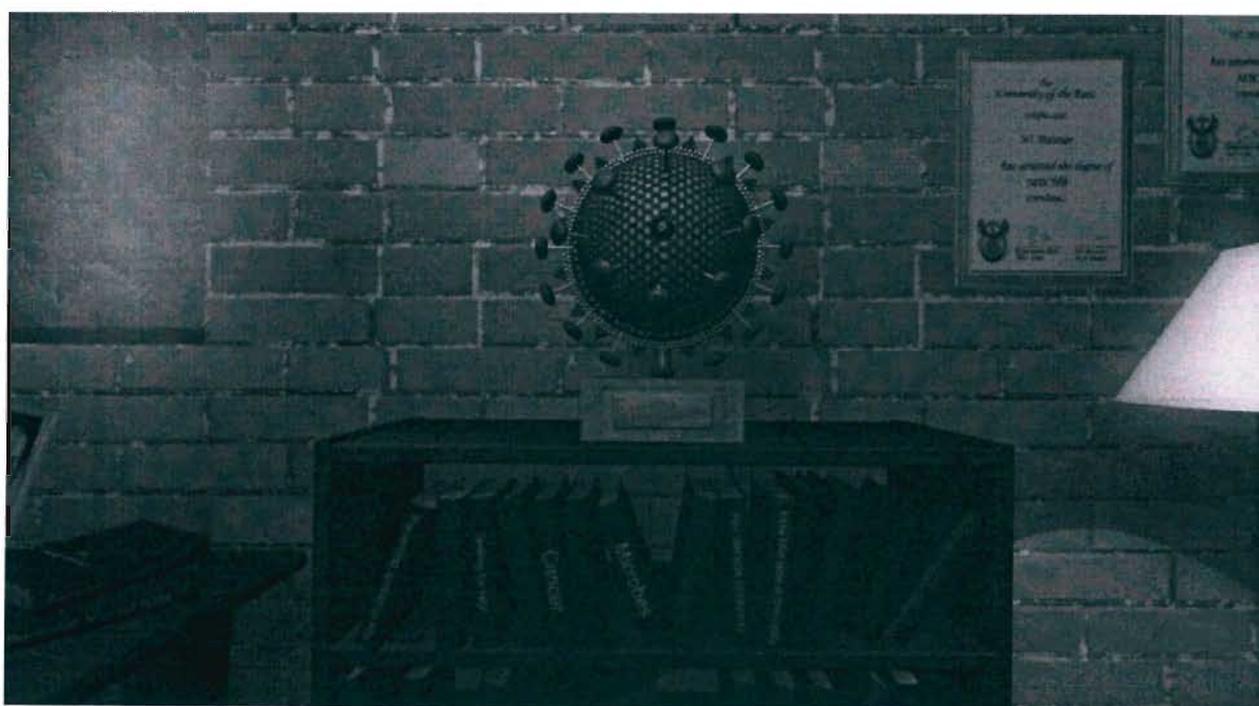
The first part of the puzzle comprises the content space and this is in the form of important readings addressing the infective mechanism of HIV/AIDS in the human body. The articles that are in the books on the doctor's bookshelf provide learners with clues and knowledge specifically related to the way in which HIV binds to lymphocytes in the human body, and why the destruction of these cells is damaging to our health (Figure 4.9a). The learners will need to access this information in order to solve the second part of the puzzle. Learners can either choose to read the information first and then attempt the puzzle or vice versa and they can move freely between the two puzzle spaces at any stage during the puzzle solving process.

The second part of the puzzle deals with the physical interaction of the HI virus with lymphocytes in the human body. The puzzle interface for this stage of the puzzle process is a 3 dimensional model of an HIV-1 virus (Figure 4.9b). This gives learners an idea of the 3D morphology of the HI virus, as well as an insight into what other viruses look like. Protruding from the surface of this model are numerous club-like objects. Learners can find out from reading the books related to this puzzle on the bookshelf, as well as looking at the clue on the doctors deskpad (Figure 4.9c) regarding the globe puzzle, that these represent the gp120 proteins displayed on the surface of the HI virus. These proteins are particularly important because they are instrumental in the process of binding to the T-lymphocytes before fusing membranes with them. This is the key to how HIV gains entry into the lymphocyte cells.

The purpose of this puzzle is to demonstrate the biological entity behind HIV/ AIDS and to link the collapse of the immune system with the life cycle of the HI virus within the human body. This is achieved through the close interaction of the learners with the 3D HIV-1 model and through a simulation showing the stages of the life cycle within the human body. The life cycle simulation shows in a more animated way the manner in which HIV infects lymphocyte cells, through initially binding with their outer protein layer, and then using the lymphocytes to produce more copies of the HI virus.

At first glance the HIV model appears to be a static model simply sitting on the bookshelf in the doctor's office. However, when the learner approaches the model and clicks on the Syntech logo on the front of the model, the two doors of the model swing open and a projection of the nuclear contents of the virus is displayed inside the model's sphere. The camera zooms into the puzzle until such a time when only 6 of the model's outer proteins are clearly visible to the learners. When the camera has completed its zoom and the viral contents are being projected, the 6 visible gp120 proteins on the periphery become green and glow

slightly. These become the buttons for the puzzle interaction interface. When the learners click on any of these buttons a specific sequence, directly related to that button, is played. Each sequence is a different part of the overall lifecycle. Whenever one button is depressed, a sequence plays. However, when the sequences are played back in the order in which they occur within the HIV lifecycle, then the entire lifecycle animation plays, the buttons return back to their inactive brown state, the camera zooms out and the puzzle doors close. Now the light on the front door of the puzzle (inside the Syntech logo) has turned green. When the puzzle is complete, the base of the HIV puzzle swivels open and reveals a key which the learners can then pick up and add to their inventory (this key is needed for a later puzzle in the laboratory).



**Figure 4.9** Puzzles relating to the structure and function of HIV-1. (a) Books from the office bookshelf displaying the type of content available to the learners while in the portal; (b) 3D model of the HIV-1 virus structure. The gp120 proteins exhibited on the surface of the model are important in the recognition of, and for gaining entrance to, T-cells in humans, (c) The Doctor's deskpad showing a clue for the solution of the HIV-1 puzzle

### *HIV window period and accuracy of AIDS test*

The second puzzle in this portal is situated in the laboratory. This puzzle addresses the concept of the window period in HIV testing as well as issues of reliability and the mechanisms of the AIDS test.

Because of a lot of controversial media hype concerning the AIDS test both locally and globally, this puzzle attempts to address the AIDS testing procedure as well as any factors that might influence the outcomes of

this test, such as the ‘window period’. This puzzle forms one of the clues as to what is really happening by means of human testing in the portal.

The purpose of this puzzle is to show learners the complexity associated with testing for HIV/AIDS. The test mechanism used here is the Enzyme Linked Immunosorbant Assay (ELISA) which is commonly used to conduct AIDS tests. In medicine today a number of different tests are used in conjunction with one another when the blood sample has tested positive for HIV. This puzzle aims to show learners some of the background behind the testing procedure regarding HIV and relates this testing procedure to the biology of the HI virus, once again linking AIDS to something more concrete than myth or superstition.

An added layer of complexity with testing for HIV/AIDS is that there is a typical window period associated with the infection. During this time (from 3 – 6 months after initial infection) antibodies to HIV are not yet detectable in the blood because the level of antibody requires time to respond to the increasing HIV count within the body. This is an important consideration when getting tested for HIV infection – a negative result obtained within the window period is a false negative and can adversely impact the way infected people handle the disease and make their life decisions.

This puzzle presents information to the learners by the way of a operation manual for the ELISA plate reader which also provides some clues as to the antiretroviral testing that is occurring in the portal. The puzzle manipulation interface itself deals with the window period and the way in which this can affect the results of an HIV test.

In the puzzle manipulation interface (Figure 4.10a) learners are told that in the process of reorganising the blood samples fridge, the patient numbers and HIV status labels fell off two ELISA plates. The only label to stay on each plate was the date on which the plate was tested. There are only two possible patients that the plates could relate to and it’s up to the learners, using a combination of finding out the HIV status of the blood samples using the ELISA plate reader, the dates on which each plate was last tested and the extra testing results information provided for each plate, to solve the puzzle of which patient label belongs to which ELISA plate. Learners can work this out based on the presence of a window period after contracting the virus and the fact that once a patient is HIV positive they can never become HIV negative again.

As an extension to this puzzle, and a part of the resolution of the game, inside the store-room is Dr Meisner’s personal testing chart where a record of all test subjects is kept. This testing chart makes explicit the fact that Dr Meisner is infecting the villager with HIV for the purposes of testing his antiretrovirals on them (Figure

4.10b). The store-room chart also shows the window period clearly and all the red dots and blue dots are explained by the wall chart labels.

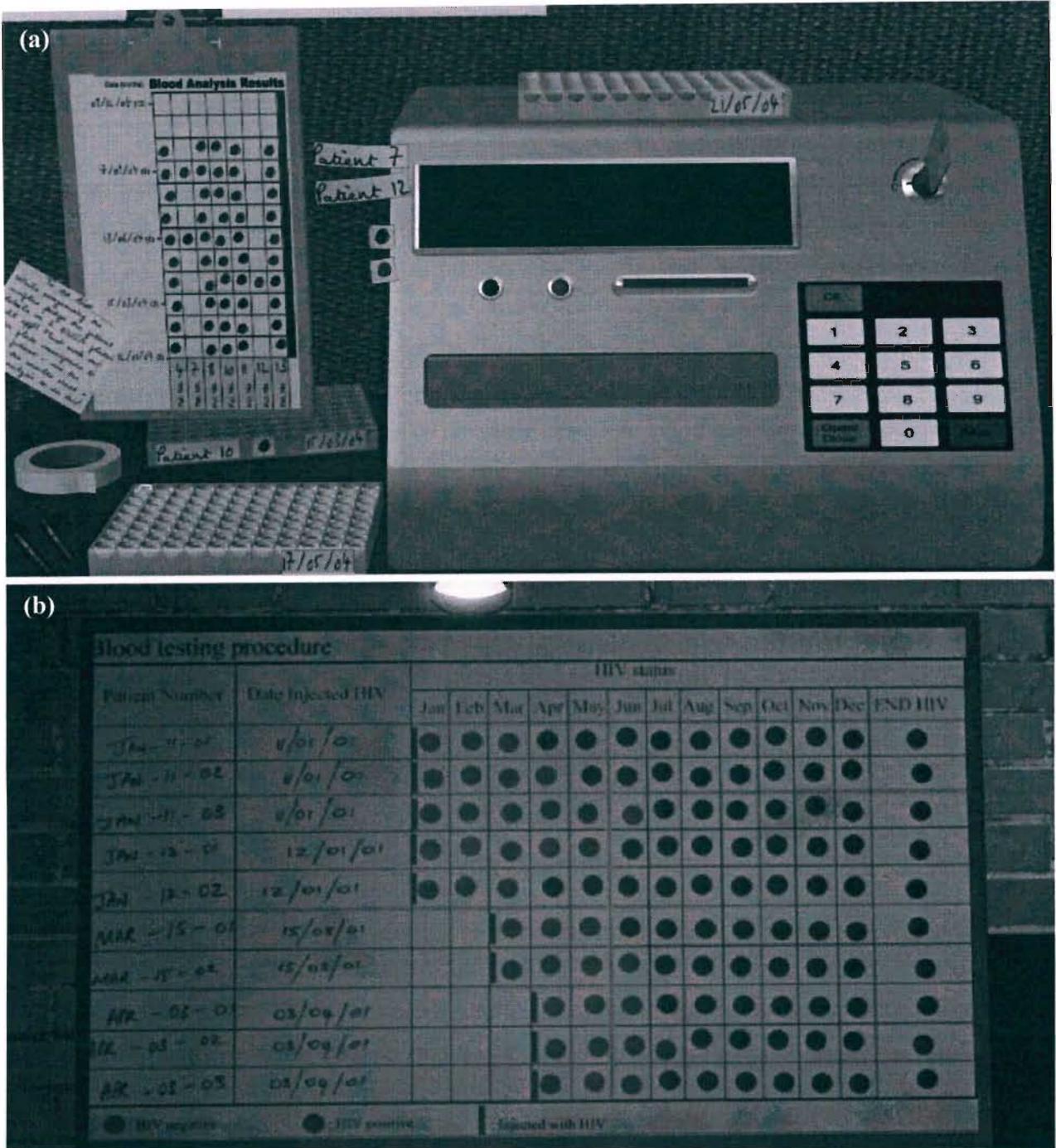


Figure 4.10 Puzzles dealing with the HIV window period and the reliability of AIDS test. (a) The ELISA plate reader used for testing blood samples for HIV antibodies. Learners can insert the two different ELISA plates into the reader and get a result; (b) The testing chart can be found in the store-room where final resolution of the game takes place. The chart graphically displays the window period of 3 – 6 months.

There is one other manifestation of this theme in the portal, and this puzzle controls access to the medical tents where Meisner keeps the test patients.

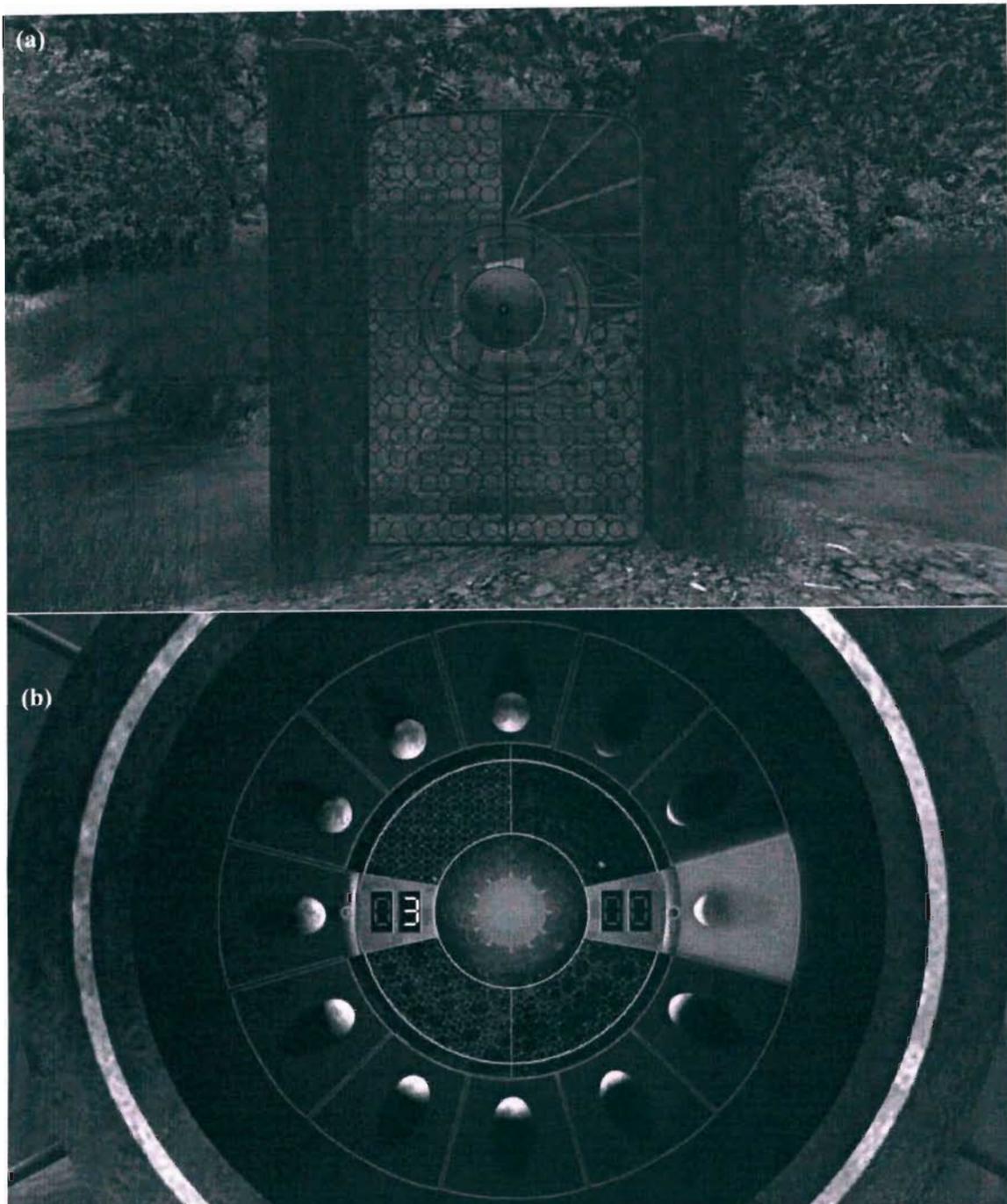
The purpose of this puzzle is to emphasise the fact that there is a window period associated with the testing and detection for HIV antibodies. This puzzle strives to let learners know that anywhere between 3 and 6 months after initial HIV infection they may be incorrectly found to be HIV negative. This is due to the titre of HIV antibody in the patient not yet having reached the lower limit of what is detectable in the HIV tests. Some of the complexities of the tests used are covered in other puzzles in the lab. This puzzle requires learners to enter the approximate window period time before the gate leading to the medical tent can be opened. Until this puzzle is solved, the learner cannot progress into the medical tent.

The puzzle interface is situated in the middle section of the gate which leads to the medical tent area (Figure 4.11a). The gate has been designed to show visually what happens with the amount of HIV in the blood with particular reference to the window period. The gate structure is divided into quarters with each quarter showing the relative amount of HIV in the blood for that part of the infection cycle (the quarters are based on the outlay of a traditional clock face). The first quarter contains no HIV patterning, whereas the second, third and fourth quarters show proportionally more HIV patterning. This corresponds to the increase in HIV titre in the blood as the infection cycle continues.

The design of the puzzle interface (Figure 4.11b) suggests two main themes, these being time and HIV. The HIV motif can be found in the main light source for the puzzle (the HIV globe in the centre of the interface) as well as the background patterns around the light source. Similar to the gate design, these background patterns convey the amount of HIV in the blood and relate the concentration of HIV to the time of the window period.

The time scale for the window period is suggested by the use of different phases of the moon arranged in a traditional clock theme (i.e. the smallest moon segment aligns with 1 'o'clock and the full moon with 12 o'clock). The moons themselves in this puzzle refer to months.

In order to solve this puzzle learners are required to activate each number panel separately (by pressing the red button to the side of the panel) and then click on the corresponding moon panel. In the left panel learners should place the number '03' and in the right panel '06'. When the puzzle has been solved the learner gets visual feedback which includes the highlighting of the moon panels that correspond to the full window period.



**Figure 4.11** The bridge gate puzzle. This puzzle addresses the window period where HIV cannot be detected for up to 3-6 months after initial infection. The puzzle consists of the following 2 components: (a) the whole bridge design. The patterning on the bridge relates specifically to the amount of HIV in the blood with respect to the window period. In the first quarter no HIV is present, whereas in the subsequent quarters progressively more HIV is present; (b) the puzzle interface has been designed to convey the use of two main themes to learners, namely time (months) and HIV concentration. Time is conveyed through the use of a traditional clock interface and specifically the concept of months is conveyed through the use of different moon phases. The HIV theme is conveyed through the inclusion of the HIV globe and background HIV patterning.

The intensity of the light behind the panels increases with increasing number of months to also link the HIV concentration in the blood again to the window period concept. In addition, the HIV motifs at the centre of the interface light up to highlight the presence of HIV in the cycle.

This puzzle, therefore, requires learners to read the information available in the doctor's office, perform the ELISA tests and solve the puzzle in the laboratory. Once learners have done this, they will have to internalize this information and link HIV antibody testing to the window period. The section of the puzzle at the bridge reinforces the window period concept, whilst the store-room wall chart makes explicit in a graphical sense, the existence of the window period.

#### *Modes of HIV transmission and symptomatic expression of HIV infection*

This puzzle deals with the modes of HIV transmission. The story context for this puzzle is that Carua, the lab assistant, has started making a poster detailing the ways in which HIV can spread and what symptoms to look out for if you suspect you have contracted the HI virus. This pictorial poster is borne out of the need to stem the apparent spread in HIV infection within the village. The poster is in the early stages of completion with all the pictures cut out and ready to be pasted beneath the correct pre-existing headings on the poster. Learners will be required to paste the correct images in the correct areas of the poster to solve the puzzle. Information concerning the transmission routes of HIV and symptomatic expression is embedded in the previous two puzzles described above and should be accessed before this puzzle is attempted.

This puzzle allows learners to access information regarding the transmission of HIV and organize this information in a logical manner. The importance of this puzzle lies in the way it requires learners to identify the ways in which HIV is transmitted and then think about the symptoms that are exhibited once transmission has occurred. Instead of simply reading this information, the puzzle process demands that learners operate on and transform the information in the process of puzzle completion. Information learned in this way is more likely to be recalled in future and could have a strong positive association with preventative measures and resultant behaviour changes in learners.

#### **4.7.2 Malaria puzzle**

The malaria puzzle situated in this portal addresses the issue of malaria awareness and prevention strategies and requires the learner to assimilate information regarding malaria prevention before then linking concepts pertaining to the lifecycle, prevention and pathogenesis of malaria infection.

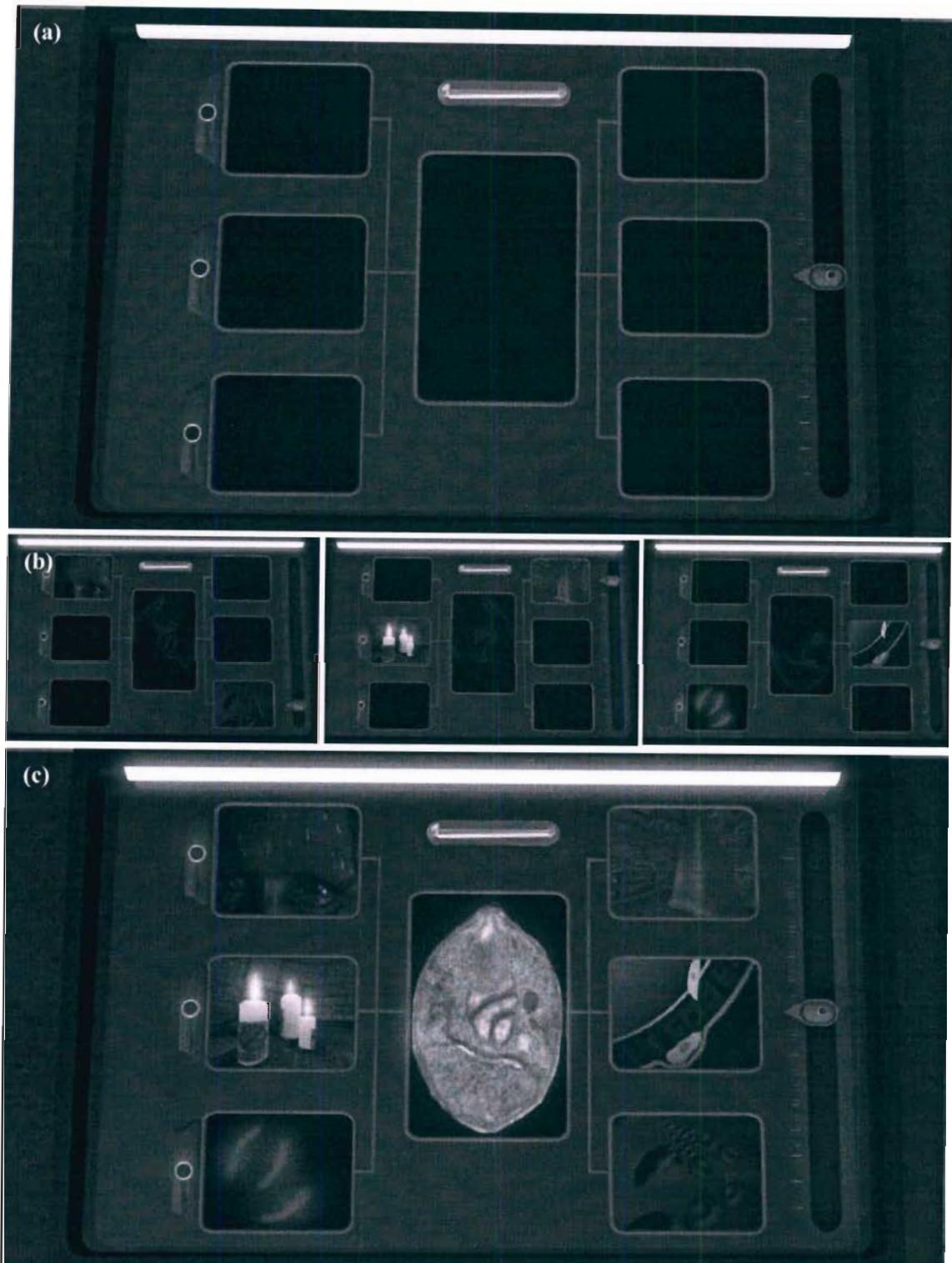
### *Malaria causative organism and pathogenesis of malaria*

The purpose of this puzzle is to help learners consolidate some of the information they have seen regarding malaria in the portal. Three concepts dealt with here are the way in which the biological organism would cause the symptoms that exhibit with malaria infection, prevention of malaria at grass roots level and some of the latest more technological research linked to prevention, and specifically linked to disturbing the lifecycle of *Plasmodium falciparum* in mosquitoes.

The 3 concepts are displayed along the left side of the panel and pictures appear at random on the right side of the panel (Figure 4.12a). What the learner needs to do is link the concept on the left to the appropriate image on the right. This is done by first clicking the selector button immediately to the left of the concept image, and then by dragging the slider on the right of the panel until it is flush with the correct corresponding image on the right.

With each combination of concept image and image chosen on the right, a shape is illuminated in the central screen area (Figure 4.12b). When a concept is correctly matched with the corresponding picture then the shape that is displayed stays visible in the central console, even when other combinations are entered by the user. The purpose of this is that when the 3 concepts have been linked correctly the shapes that are displayed make up an outline of a merozoite – one of the asexual stages of *falciparum* in humans (this stage is important and distinguishable because it is directly correlated with the appearance of malarious symptoms).

Once the puzzle has been solved and the correct outline is showing, a picture of a stained merozoite fades in behind the outline, making it obvious that the outline refers to a biological agent (Figure 4.12c). Immediately after this fading in of the image, a slide is ejected out of the panel interface which contains a picture of the merozoite. This is the malaria slide that is necessary for the solving of the final resolution puzzle.



**Figure 4.12** The malaria puzzle interface situated in the laboratory. (a) The concept images are displayed down the left side of the panel while the linking images are displayed randomly on the right of the panel (b) Three correct associations between the concept images on the left and the corresponding images on the right. (c) The final result of the puzzle being solved. Here the 3 correct patterns in the central console have been overlaid to show the outline of a merozoite, and a stained slide of a merozoite in the central console.

The importance of this puzzle is that learners are again required to assimilate new information (from the malaria poster) before then transforming this information and matching the concepts. This process encourages learners to think more in depth about the information presented on the poster. The end result of this puzzle is that learners should be more aware of the possible preventative measures that exist against malarial infection, some of the research being done to halt the spread of malaria and some of the symptoms of malaria infection. The portal surroundings have also been designed to reinforce this principle by the inclusion of citronella candles and mosquito nets in the village and the medical tent.

### 4.7.3 Tuberculosis puzzle

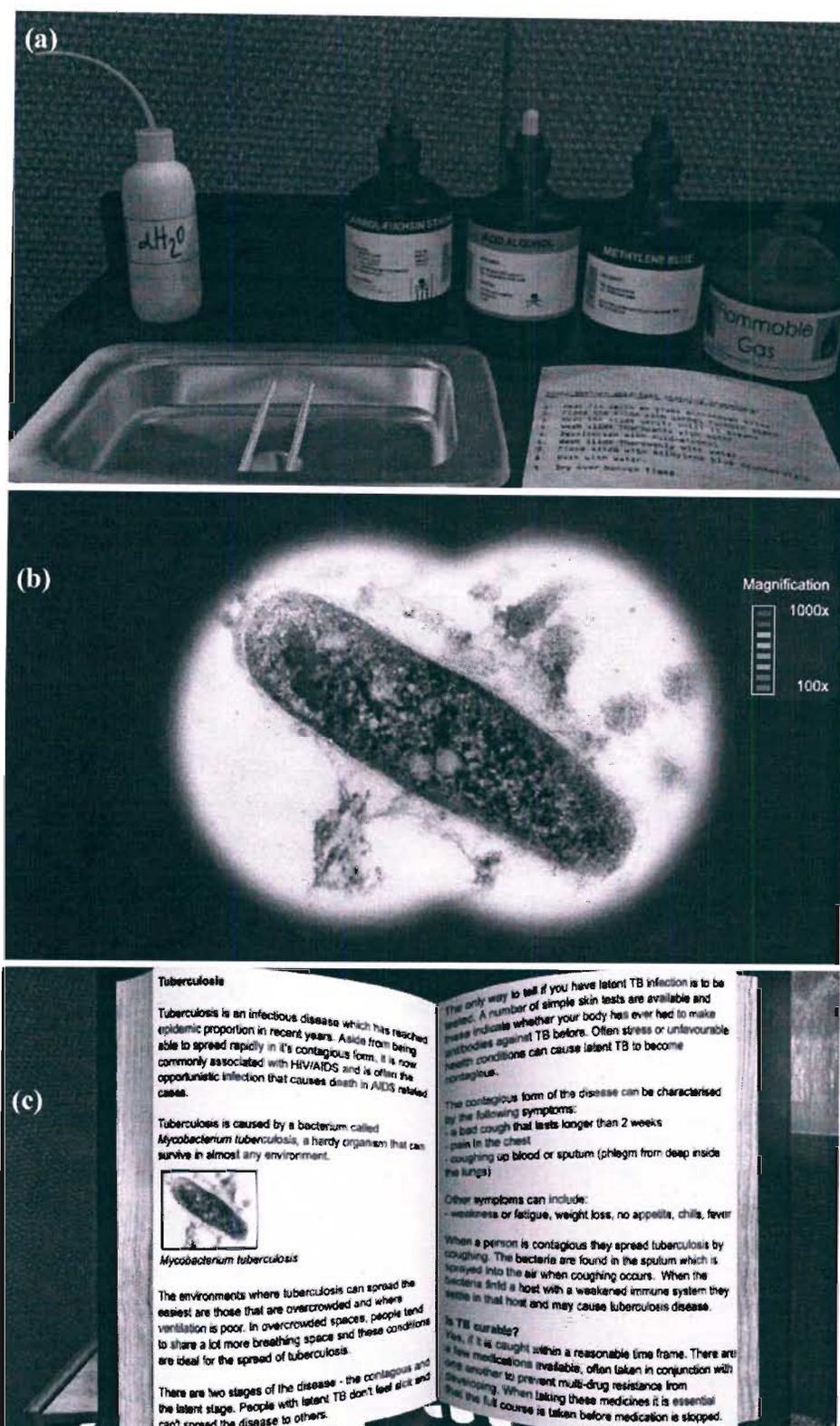
The tuberculosis puzzle strives to incite in learners the knowledge that tuberculosis is contagious and that the resultant spread of tuberculosis across a population is also dependent on the living standards and degree of contact within that population. The biological causative organism, a bacterium, is also defined as the infective agent in tuberculosis.

#### *Causative organism of tuberculosis*

In the medical tent learners can look at a prepared sputum test slide through the microscope (Figure 4.13a). Before being able to see anything, though, learners have to 'stain' the bacterium responsible for causing tuberculosis. They do this by learning about the staining procedure (Figure 4.13b) and then applying that to the puzzle process. The purpose of this is two fold: firstly learners should gain an appreciation of the size and the 'invisible' nature of bacteria in the environment when viewed with the naked eye.

Simply because learners cannot see these organisms does not mean they are not present. Secondly, by doing this learners become more aware of the causative organism of tuberculosis and the way in which TB is most frequently and accurately tested. Learners can also gain an appreciation for the general structure of bacteria (this reinforces the differences between viruses and bacteria as dealt with by another puzzle in this portal).

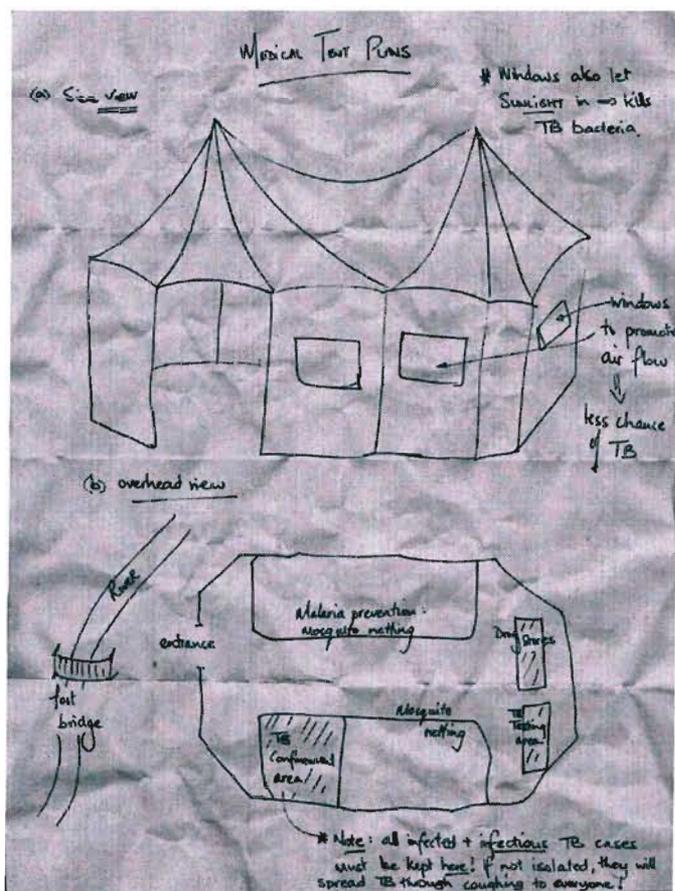
Applicable texts concerning TB are also available in one of the books in the medical tents (Figure 4.13c). Articles that appear in this book discuss the bacterium responsible for causing TB, the general symptoms of TB and the method of transmission.



**Figure 4.13** (a) The puzzle interface for the tuberculosis puzzle showing the various stains and anti-stains, the Bunsen burner, distilled water and the instructions detailing the Ziehl-Neelsen stain technique used in the DOTS treatment strategy. (b) Once the staining procedure has been successfully carried out learners are able to view the stained sputum test slide using the microscope in the medical tent. (c) The Tuberculosis book situated in the medical tent.

### Tuberculosis modes of transmission

This part of the puzzle is more reflective in nature and simply provides learners with the scaffolding they might require to internalize new knowledge concerning the transmission of TB. On the bookshelf in the medical tent are the plans for the original tent construction (Figure 4.14). Detailed in this plan are the preventative measures that have been taken within the medical tent to try and prevent the spread of TB from patient to patient. The way in which this is achieved is to ensure plenty of air flow and sunlight as well as to prevent overcrowding. Patients suffering from the infectious stage of TB disease are also cordoned off in a special holding section of the tent where they are not allowed to mix with uninfected patients. The knowledge presented to learners in this tent plan makes explicit a few principles, one of which is that tuberculosis is contagious at certain stages of the disease and not contagious, but still harmful, at others. The tuberculosis bacterium also thrives in conditions where there is limited sunlight and fresh air and where overcrowding occurs. Whilst TB can indiscriminately affect anyone, it is sadly those with poverty stricken lifestyles that are worst affected because of the conditions under which they are forced to live.



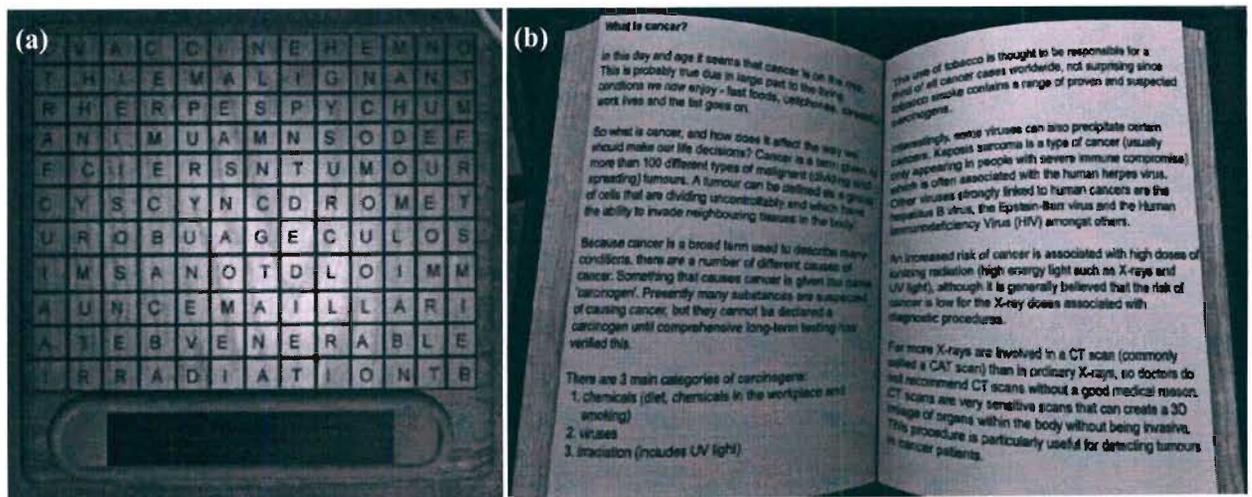
**Figure 4.14** Construction plans for the medical tent showing the ways of minimizing the incidence of malaria and the spread of tuberculosis. Mosquito nets are used to stop the malaria infection in critical patients, and a patient confinement area is set aside for patients infected with tuberculosis.

#### 4.7.4 Cancer Puzzle

The cancer puzzle is situated in the doctor's office and takes the form of an interactive reading study and crossword puzzle. Inside the doctor's personal journal are various newspaper clippings, letters and interesting articles relating the causes, biology and mechanism of spread of cancer to learners. This text also informs learners about significant steps that have been taken by South African researchers to contribute to the global knowledge on cancer.

The crossword puzzle is also situated in the doctor's office on one of the work desks (Figure 4.15). At the bottom of the crossword puzzle interface is a screen and a progress monitor. The questions that learners need to answer to solve this puzzle appear on this screen. Answers to the questions are spelled out using the crossword interface. When the learner has answered a question correctly, the progress bar indicates the percentage of the puzzle completed. This facility provides the learners with navigational information and prevents the kind of frustration indicative of confusion about the mechanism or length of the puzzle. The answers to the questions asked are all available in the texts dealing with cancer in the doctor's journal.

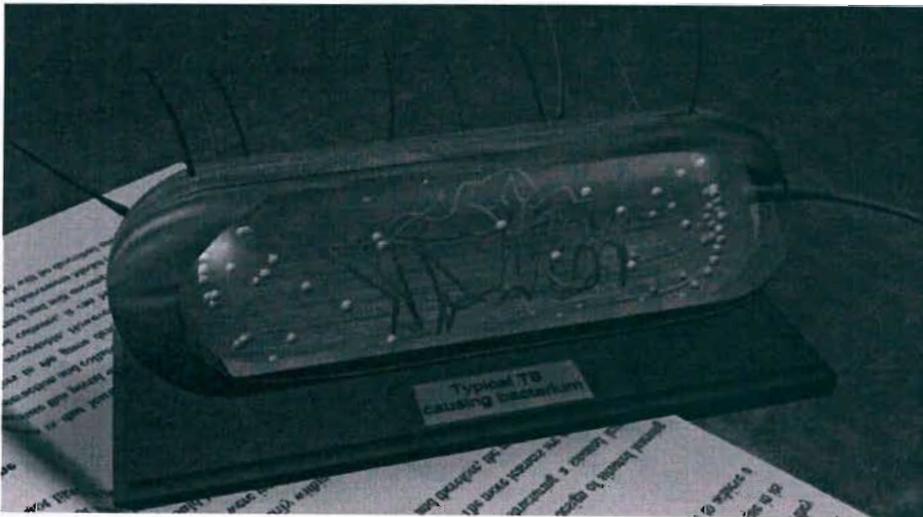
This puzzle will impart an appreciation for various aspects of cancer, including the basic conditions for cancerous development, the prominent causes of cancer and the treatment of this condition.



**Figure 4.15** Cancer puzzle situated in the Doctor's office. (a) The crossword puzzle interface makes it reasonably intuitive that solving the puzzle has something to do with word formation. The black LCD is where the questions are asked of the learners. If the puzzle is completed successfully, the black LCD slides open to reveal a quarter key which is used elsewhere in the portal. (b) Some of the resources needed to complete the puzzle.

### *The Differences between Viruses, Bacteria and Protists*

Whilst no single puzzle exists to support this learning, a number of different models contribute toward distinguishing the difference between viruses, bacteria and protists. The concept of viruses is dealt with in the HIV texts and the 3D HIV-1 model in the doctor's office. Also inside the doctor's office, on the main desk lies a paperweight model of the basic body structure of a tuberculosis-causing bacterium (Figure 4.16). In the medical tent, learners can also see the shape of the bacterium responsible for tuberculosis. In the laboratory, learners can see what protists look like both from looking at the posters concerned with the life-cycle of the plasmodium protist and from engaging with the malaria puzzle interface where they see merozoites in the blood and can see their morphology.



**Figure 4.16** A 3D model of *Mycobacterium tuberculosis* (the causative organism of TB) situated on Dr Meisner's desk in the office.

#### **4.7.5 Conceptual Summary puzzle**

This puzzle requires learners to link all the information they have acquired regarding HIV/AIDS, tuberculosis, malaria and cancer and “see the bigger picture” of how they all inter-relate in disease progression in real life. The concept this puzzle tries to get learners to think about is that HIV disease attacks and compromises the immune system first. When the immune system is low and cannot cope with fighting off other diseases, what are termed opportunistic infections set in. It is these opportunistic diseases that are often responsible for the death of AIDS sufferers.

The mechanism of the puzzle requires learners to link a picture related to a specific disease to the name of that disease, and then rank the diseases in a chronological order of sorts (Figure 4.17). As long as HIV/AIDS is

placed in the first chronological time slot, the rest of the diseases can follow in any order. Once the learner has managed to achieve this, access to the store-room, where the final resolution of the game mystery occurs, is permitted.



**Figure 4.17** The conceptual summary puzzle. The puzzle guarding the entrance to the store-room requires learners to link the different diseases that have been covered throughout the portal. Learners are then required to list the different diseases in chronological order of infection. HIV/AIDS must come first, followed by the opportunistic infections in any order.

#### 4.8 Conclusion

By playing this game, learners will be exposed to numerous content areas, each with its associated puzzle space. The content space for each domain will provide learners with reference material and scaffolding structures with which to build on their prior knowledge. By using and manipulating this information, learners are encouraged to reflect on this information and even reflect, in a metacognitive manner, on their own puzzle-solving strategies. Through the process of reflection, transformation and accommodation of the material in a contextualised environment, learners may truly internalize new knowledge and gain deep understanding of the knowledge domain.

The Game Achievement model provides a reductionist framework for puzzle design and, therefore, does not adequately detail ways in which to effectively build educational puzzles. In addition, this model does not make allowance for the inter-relation between puzzles, or for the inclusion of a conceptual summary puzzle. The puzzle process model was devised to aid designers in future puzzle design endeavours. This model made

explicit the need for two components, the content space and the puzzle space, each important for the role they play in the puzzle process. The purpose of the content space is to create cognitive conflict in learners and to supply them with the content they would need to assimilate in order to render themselves capable of solving the puzzle. The puzzle space is the part of the model where the manipulation of the puzzle components takes place and, hence, where the puzzle solving occurs. Within this space, reflection and internalization are encouraged to promote the formation of implicit knowledge, or deep learning.

A further model, the conceptual summary model, is proposed for use in future situated learning environment designs. This model makes allowance for the interconnectedness of different puzzles and, in an attempt to promote cognitive and metacognitive skills within the learning environment, calls for a structured hierarchical approach to puzzle design within situated learning environments. In other words, the model promotes the building of one puzzle on knowledge gained from a previous puzzle. The process of solving the conceptual summary puzzle therefore requires learners to reflect on information learned in previous puzzles and then integrate this information into new cognitive structures in order to realise the manner in which this information is connected to other phenomena.

## CHAPTER 5

### TESTING OF THE GAME ENVIRONMENT

#### 5.1 Introduction

The main purpose of formative evaluation is to provide information which can be used in guiding the design and enhancement of interactive learning systems at various stages of their development (Reeves and Hedberg, 2003). Formative evaluation is probably the most important aspect of the entire learning system development process, often yielding the most significant contribution of any function in evaluation (Reeves, 2000). However, formative evaluations of these systems are generally not well done. Reeves and Hedberg (2003) contend that most designers of interactive learning systems fail to conduct adequate evaluations. Some radical constructivists argue that you cannot test for knowledge using techniques that are removed from the context of learning, for example writing a test to show that you have learnt how to write a computer program (Boyle, 1997). Furthermore, evaluation methods used in interactive learning systems tend to underestimate the growth in cognitive and learning processes due to the decontextualised nature of most assessments (Brown, 1989).

What is needed is a contextualised evaluation strategy that addresses complex problems associated with interactive learning environments, and this approach should be coupled with rigorous reflective inquiry to refine these innovative environments and inform new design principles (Collins, 1992). Van den Akker (1999) defines 'development research', an approach that aims at making both practical and scientific contributions. This form of research includes the evaluation and testing of solutions in practice before documentation and reflection of the process can produce more generally applicable 'design principles' (van den Akker, 1999; Reeves, 2000).

Qualitative evaluation provides rich information usually more useful in shaping design, whereas quantitative methods provide a more objective measure, but may be lacking in richness of information (Boyle, 1997). In many cases a mix of the two kinds of evaluation provides the most suitable evaluation strategy (Boyle, 1997; Reeves, 2000). Laurillard (2001) advocates a combination of observation, interview and a trace of the learner's performance as an effective combination for elucidating the processes of learning. In addition this author recommends that learners should be allowed to interact with the learning environment undisturbed and then be asked to give a retrospective account in working through the exercise. A trace of the learner's encounter is then used by the interviewer to focus the learner's explanation on why they followed a certain strategy (Laurillard, 2001).

Reeves and Hedberg (2003) recommend that formative evaluation strategies include expert review, user review and usability testing as well as field tests of the prototype program when it is ready for release. The combination of quantitative and qualitative analyses in the form of interviews, questionnaires and learner usability observations allows researchers to make a more definitive analysis of the learning outcomes of interactive learning environments.

## **5.2 Methods of evaluation**

The research methodology adopted in this part of the study aims to make a serious contribution to the testing, documentation and reflection required to verify the design principles followed in this portal. In order to make evaluation as beneficial as possible a mixed-methods evaluation (Reeves, 2000) approach was adopted here. In particular, this study made use of a four-tiered approach to the evaluation of user-testing, incorporating the use of expert review, pre-gameplay and post-gameplay questionnaires, learner observations and audio recording during gameplay, as well as post-gameplay learner interviews. This qualitative and quantitative information will be combined to look at various aspects of interactive educational environment design

### **5.2.1 Expert review**

Reeves and Hedberg (2003) contend that expert review may be the most frequently used formative evaluation strategy and with good reason. According to these authors, content experts are probably the most important expert sources of information for education and training products. Verifying that the content in an interactive learning environment is accurate is of utmost importance because if it is incorrect then the learning environment could possibly mislead learners. For the purposes of formative evaluation, an expert can be defined as anyone with specialized knowledge that is relevant to the design of the interactive learning environment being evaluated (Reeves and Hedberg, 2003).

Because the learning objectives in this portal were primarily concerned with the transmission, biology, symptomatic expression and prevention of HIV, 3 experts in the field of HIV research and bioethics were engaged in the expert review process. An average expert consultation lasted in the region of 80 – 90 minutes. The interactive learning environment was demonstrated to these experts and then they were given an opportunity to navigate through the learning environment.

The experts were asked to provide input regarding a number of different game situations, for example where: (1) elements of the game environment were being used to communicate the underlying story of the portal, (2)

puzzle interfaces were found in the game environment, and (3) content areas were found in the game environment.

More specifically, time spent with the experts was structured to ensure that all the tasks were completed in the time and that there was ample opportunity to record their feedback on key aspects of the game. An example of the discussion guide can be seen in Table 5.1.

**Table 5.1** An example of the discussion guide followed during expert interviews. These interviews were broken down into numerous task times to ensure all topics were covered and that the experts had ample time to engage with the portal interface.

Time allocated	Task to be conducted	Extra notes
15 mins	Thank you for seeing me. Explain the concept of the portal and the inner city to the expert. Explain what is behind this project.	
50 mins	Encourage the expert to become more acquainted with the interface and familiarize themselves with the navigation aspect of the portal. Observe and take notes as they manoeuvre through the environment. Enter into dialogue with expert over the following areas/ interface: <ul style="list-style-type: none"> <li>• Burning ground area (storyline)</li> <li>• HIV 3D model puzzle (doc office)</li> <li>• Interaction with Meisner in office</li> <li>• Cancer crossword puzzle (doc office)</li> <li>• Bridge gate puzzle (external area near medical tents)</li> <li>• Interaction with Meisner and Carua (Medical tent)</li> <li>• Interaction with TB puzzle (medical tent)</li> <li>• Verify the content placed in puzzles</li> </ul>	
15 mins	Summarise main points covered and check accuracy of perception. Thank for time	

The information yielded from the expert interviews was then collated, transcribed and organized into main themes across all expert responses using NVivo (QSR). This software is useful for the organization of transcripts into themes and facilitates easy design of conceptual models based on these themes.

### 5.2.2 Pre- and post-gameplay questionnaires

Identical pre- and post-gameplay questionnaires (Appendix D) based on those that were used in the definition of the learning objectives for the portal were constructed. Only questions pertaining to content areas that were to be included in the testing version of the portal were included in the questionnaire. An additional eleven open-ended questions were included in the questionnaire. These open questions were concerned primarily with the content areas addressed by the puzzles available for testing in the portal environment. Figure 5.1 shows an extract from the questionnaire, showing one closed and one open question format.

8. What is the most prevalent form of HIV transmission in Africa?

a. Mother to baby transmission.

b. Heterosexual (two sexes) sex.

c. Homosexual (same sex) sex.

d. Blood transfusions.

e. Needle sharing amongst individuals.

<i>Confidence</i>			
1	2	3	4

14. What do we mean when we talk about the HIV window period? How would you describe it to someone who'd never heard about it?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

<i>Please rate your confidence in your description</i>			
1	2	3	4

**Figure 5.1** An excerpt from the pre- and post-gameplay questionnaire showing an example of a closed and open-ended question.

Multiple choice questions were included to facilitate a quantitative aspect to the comparison between pre-and post-gameplay scores while open-ended questions were included to increase the richness of the information obtained from learners. These open-ended questions would be used to assess whether, as a result of interaction with the puzzles and the associated social discourse that resulted, learners had acquired a richer understanding of the topic being addressed.

When comparing the pre- and post-gameplay questionnaires, the multiple choice questions were coded as either a value of 1 (correct answer) or 0 (incorrect answer) and recorded in a SPSS (SPSS for Windows, version 11.5) spreadsheet along with the learners confidence in their answer. The number of questions answered correctly in pre- and post-gameplay questionnaires were then compared as well as the confidences with which these questions were answered.

The open questions were analysed differently to make full use of the richness of the information being portrayed by the learner. What was essentially being measured here was the information that learners volunteered and considered as being relevant at the time of answering the question. In addition to their answers, learners were also asked to specify the confidence they had in the answers they had provided. This was done to ascertain how convinced the learners were that the information they had supplied was correct.

Anderson *et al.* (2001) define 'content analysis' as being a set of procedures that identify a target variable, collect representative examples from the text, and devise reliable rules for categorizing segments of the text. In a study describing online asynchronous discussions Blignaut and Trollip (2003) formulated a way in which to quantify open-ended responses by placing the responses into different categories, based on the topic they were addressing. They took transcripts from online asynchronous discussions and categorized each response according to the content in that response. They reported that having a taxonomic framework within which to categorise information was a very useful tool for understanding some of the dynamics of that information.

In an attempt to understand the dynamics of the information retrieved from respondents in the open-ended questions for both pre- and post-gameplay questionnaires a similar approach to Blignaut and Trollip was adopted. In the context of this study, however, it was deemed more appropriate to categorise the information from the open-ended questions according to the number of relevant concepts presented in each answer, as well as the number of relevant domain-specific terms used. The reason relevant concepts were identified was because these are the base units of the answers provided and these give insight into the learner's existing knowledge structures concerning that knowledge domain. Relevant terminology was also measured to see if the interaction with the puzzle interface and the content space of the puzzles resulted in the learner utilizing some of the formal language associated with the knowledge domain.

In order to assess whether learners gained a richer understanding of the knowledge domain during gameplay, all of the pre- and post-gameplay answers were deconstructed into their constituent concepts and then each of these concepts were either categorised as being relevant or irrelevant to the question being asked (Table 5.2). In addition, the level of terminology was assessed by recording the number of relevant terms used in each response. Relevant terminology tended to be more formal language and often medical in nature.

Once all answers had been deconstructed all the relevant constituent concepts were added up and concept scores were assigned to the pre- and post-gameplay answers provided. Similarly pre- and post-gameplay terminology scores were assigned for the number of relevant terms in each respective answer.

After all the open-ended questionnaires had been similarly scored, these scores were compared and graphed using SPSS to elucidate any trends between pre- and post-gameplay answers provided by the learners.

**Table 5.2** An example of the deconstruction, categorization and terminology assessment of one of the pre- and post-gameplay answers provided by a learner.

<b>Question 15:</b> If someone asked you to briefly explain what happens when a person becomes infected with HIV/AIDS what would you say? Please include descriptions of the lifecycle and disease progression in your answer.					
Time	Learner answer	Relevant constituent concepts	Relevant terminology	Conc score	Term score
Pre-	The person will start to lose strength as his immune system starts to fail. The HIV/AIDS starts to eat or kill the antibodies which fight off sickness and the person becomes ill more frequently. Person's lifespan after contracting HIV/AIDS varies.	<ol style="list-style-type: none"> <li>1. person will lose strength</li> <li>2. his immune system will start to fail</li> <li>3. HIV/AIDS eats/ kills antibodies</li> <li>4. antibodies fight off sickness</li> <li>5. if antibodies die then become ill more frequently</li> <li>6. lifespan after HIV/AIDS varies</li> </ol>	<ol style="list-style-type: none"> <li>1. immune system</li> <li>2. antibodies</li> </ol>	6	2
Post-	The person will start to lose strength when his immune system starts to fail. The HIV virus affects the white blood cells by changing their normal mode of operation thus destroying their function and eventually spreading to other white blood cells. Because the antibodies are dying the immune system fails meaning the person becomes ill more often. Expected lifespan after infection depends on person infected and medication but it varies.	<ol style="list-style-type: none"> <li>1. person will lose strength</li> <li>2. his immune system will start to fail</li> <li>3. HIV virus affects white blood cells</li> <li>4. HIV changes normal operation of white blood cells</li> <li>5. HIV spreads to other white blood cells</li> <li>6. HIV kills antibodies</li> <li>7. if antibodies die, immune system fails</li> <li>8. if immune system fails, get sick more often</li> <li>9. lifespan after HIV infection with HIV depends on person,</li> <li>10. lifespan after HIV infection depends on medication</li> <li>11. lifespan after HIV infection varies</li> </ol>	<ol style="list-style-type: none"> <li>1. Immune system</li> <li>2. White blood cells</li> <li>3. Antibodies</li> <li>4. medication</li> </ol>	11	4

### 5.2.3 Learner observations during gameplay

Observation of learners engaging with the learning environment is a valuable experience as it allows designers to see what parts of the portal environment might be difficult to navigate or ineffective in some way (Reeves and Hedberg, 2003). The design of the portal should be self-explanatory and intuitive enough for learners to navigate through the environment without problems. In this type of formative research, learners are placed in front of a prototype environment and allowed to play in order to get feedback for the next stage of production (Newman, 1992). The aim of these observations was that from the feedback acquired through various observation techniques the author could discern some measure of how effective or ineffective the puzzle interfaces might be at achieving the purpose for which they were designed. A key part of the analysis is to examine how the technology was understood or used differently from the initial assumptions of the designers (Newman, 1992). According to Boyle (1997) the main advantages of learner observations are that it provides direct evidence of the system's effectiveness and usability, it is easy to use informally and it can also be applied as a structured technique incorporating sophisticated recording of behaviour.

In this study 7 groups of 2 learners each (total sample size of 14 learners) were asked to explore the portal environment for between 60 and 90 minutes, during which time they were observed directly by the researcher as well as having their audio conversations taped onto audio cassette. Each of the learners explored the portal environment on their own computer, but learners were assigned partners with which to work through testing. Collaborative group learning is a well established educational strategy (Brailsford *et al*, 1997) as it encourages learners involved in the testing process to verbalise their reasons for making certain decisions. Learners were thus encouraged to verbalise to their partner, and occasionally the facilitator, why they made the decisions they did regarding the puzzle interfaces or general movement within the environment and in this case was particularly effective at encouraging the "think aloud" strategy (Reeves and Hedberg, 2003). Partners were naturally assigned to two computers alongside one another in a computer LAN. This audio recording was done to capture all the discussions that occurred between the players in their pairs while interacting with the puzzles and exploring the portal environment. The conversations from these audio tapes were later transcribed and then analysed using NVivo (QSR) to search the interactions for similar themes between different learner groups.

In this study a methodology similar to that recommended by Laurillard (2001) was followed where learners were observed during gameplay and were mostly left to explore the environment uninterrupted. When they had finished interacting with an area or puzzle interface then they were asked a few questions pertaining to that interface and what they perceived the interface was about. While Laurillard prefers learners to complete their interaction with the environment before being asked questions regarding the strategies they employed in

the environment, this approach wasn't practical within the context of a spatially extensible exploration area as in this portal. The return to previously visited puzzle interfaces again after initial gameplay would essentially have doubled the time requirements for interacting with the portal environment. Instead, learners were allowed to complete their interaction with the puzzle interfaces before the facilitator engaged the learners in a dialogue concerning the puzzle solving strategies they had employed. In this sense the input from the learners was retrospective and the learners had completed the puzzle without input from the facilitator. Because the facilitator was on hand to observe the methodology being used by the learners, their method of solving the puzzle was used as a trace from which to draw out their experiences of the puzzle and their reasons for using their chosen method of puzzle-solving.

A reflective journal of these dialogue interactions was maintained. In addition to the audio tape of the interaction between the two learners while exploring the environment, their dialogue with the facilitator was also recorded for later analysis. Both the reflective journal and transcripts from the audio recording were analysed using NVivo and common threads were sought between different discussions.

Key aspects that were being sought in this stage of the evaluation were whether the portal environment was functional (i.e. did it work as it was designed to work?) and whether it was usable (i.e. could the intended learners actually use the program) (Reeves and Hedberg, 2003). Most importantly, though, was to assess whether learners could understand and engage with the puzzle interfaces in a meaningful way. In other words, did learners understand what was required of them and if not, could they find the resources they required to come to this understanding?

#### **5.2.4 Post-gameplay interviews with the learners**

Post-gameplay interviews with the learners took place immediately after gameplay had ended to ensure a richer quality of feedback. These interviews were informally structured and served primarily to get any volunteered feedback from the learners. These interviews were also conducted next to their area of gameplay so that if learners had any queries about certain areas of the game they could make direct queries while navigating to the area of concern if necessary. Key information sought here was whether the learners found the environment appealing and if gameplay had been an intuitive process for them. Learners were also asked if there was anything that they would change about the environment, and were asked to motivate their answers.

## 5.3 Results and discussion

### 5.3.1 Expert review

Three experts in the HIV field were consulted on the appropriateness of the portal in addressing some of the HIV concerns. Each of these experts had different insights which were useful for the future development of the portal and related portals (expert description in Appendix E).

Although the experts were asked their opinion on such things as the burning ground and the puzzle interfaces, their feedback regarding these things will be combined with the learner analysis of the portal environment. The main purpose of the expert testing is to get feedback on design issues, issues of content suitability and possible directions that should be considered in future design and development efforts.

The experts verified the information available in the portal as being true, but two of the experts raised concerns about the complexity of the language used in the portal. Their concern was that perhaps this portal was not entirely targeted towards school pupils from the age of 16 and up. The issue at hand, though, is that there is difficulty in emulating the scientific literature without using some of the biological descriptors. The third expert conceded that in her experience there was no one solution to suit everyone, but rather a range of solutions with varying application to individuals.

Another issue raised was that of the resources required to play the game. A number of the outreach programs that the experts are involved in engage in preventative education and they deal most often with people who would neither have seen a computer before nor have any kind of access to one in the future. This is an interesting dilemma not unusual in third-world countries. While it is acknowledged that there are a huge number of people without access to any technology, it would not be feasible to stop the development of these environments and bring the technology down to the lowest common denominator. The technology will become more widespread and more easily available as markets increase and products become more readily available. A good example of this is the cellular telephone market in South Africa. In March 2004 South Africa was estimated to have 14.5 million cellular phone users (Stones, 2004), a figure not necessarily anticipated at the launch of the cellular industry in South Africa a few years ago. Leading the way with innovative technological solutions is the way in which these technologies are developed and able to reach the mainstream market in years to come.

One of the experts also identified an area of content that would greatly increase the value of the learning task in the doctor's office. This was the suggested inclusion of a description of the normal immune system

function in humans. This would give the learners in the portal something to compare a weakened and compromised HIV infected immune system to. Furthermore, information relating to the HIV/AIDS field is always evolving and is in a constant state of flux. As a result, one or two minor items were highlighted which needed updating and changing to accommodate the latest literature and national trend.

Finally, two of the experts concurred that it would add value to the portal if some information on what to do once you've been infected with HIV were added to the portal environment. Something practical was suggested where learners could plot out their own treatment strategy and take ownership of their condition and manage it. While the portal was originally conceptualized as a mechanism for helping young South Africans prevent certain behaviours, the incorporation of this extra material would be beneficial and could work particularly effectively within the current framework of the Puzzle Process Model. This sort of authentic task best suits this puzzle model.

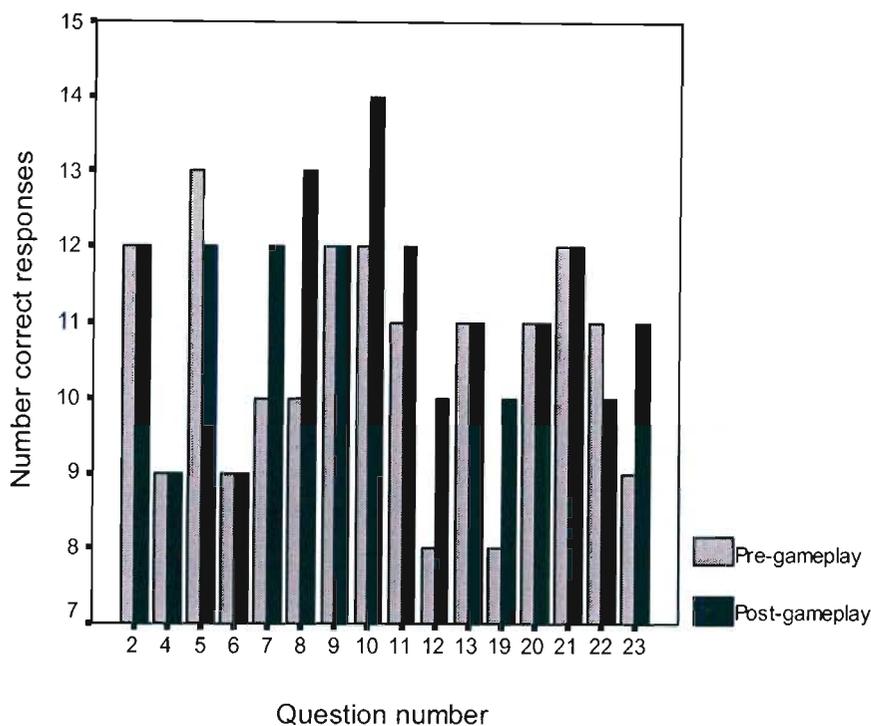
In general, all the experts thought the environment was well conceptualized, well executed and "extremely fascinating". Despite none of them ever having played a computer game before, they managed to find their way around the portal without difficulty, indicating that the interface is not overly complex and difficult to operate.

### **5.3.2 Pre- and post-gameplay questionnaires**

Due to the complexities of qualitative assessment and the rigorous demands of conducting indepth interviews and observations, sample size cannot realistically be large for the formative evaluation of a prototype system. Accordingly, the analysis of strictly empirical data is not feasible in the context of this study. However, quantitative aspects of the evaluation were still included in the pre- and post-gameplay questionnaire to see if it was possible to at least see a trend in the data when moving from the pre-gameplay questionnaire to the post-gameplay questionnaire. To this end, quantitative, categorical data from the multiple choice questions on both questionnaires were graphed to see if there was any noticeable trend between the pre- and post-gameplay knowledge states.

When the total number of correct answers for all the multiple choice questions in the pre-gameplay sample were compared with those in the post-gameplay sample (Figure 5.2) a number of interesting things became apparent. Out of a total of 16 questions, 7 (44%) of the questions were better answered in the post-gameplay sample as opposed to the pre-gameplay sample, while a further 7 (44%) of the questions were answered the same in both samples, and 2 (12%) of the questions were answered less correctly in the post-gameplay than in the pre-gameplay questionnaire.

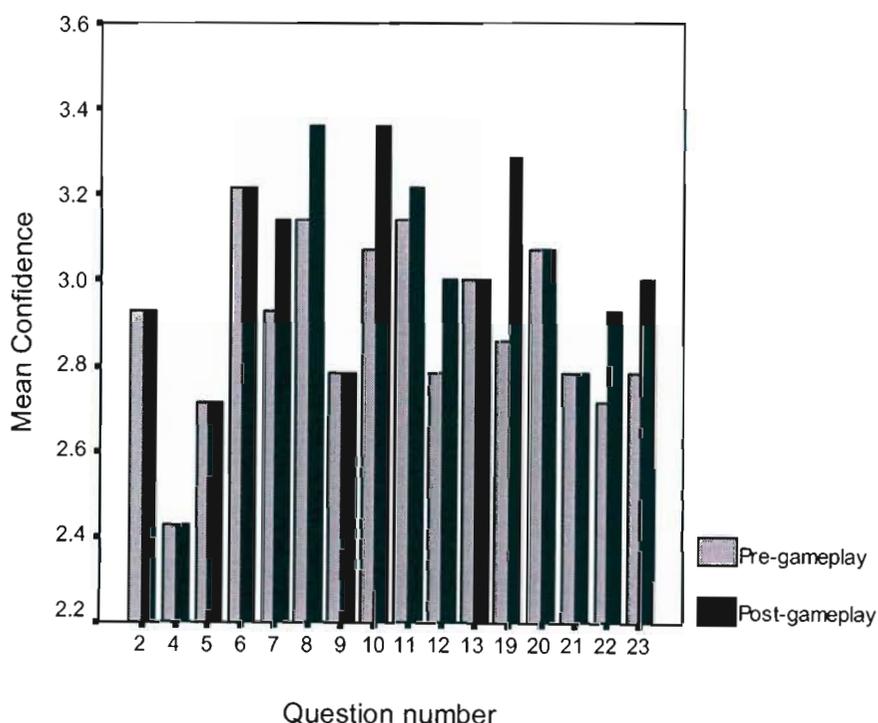
Realistically there could be a number of reasons to explain the difference in pre- and post-gameplay performance and it is not within the scope of this study to examine each of these possibilities. However, since the learners filled in the pre-gameplay questionnaires immediately before engaging in gameplay, and filled out the post-gameplay questionnaire immediately after gameplay and their interview with the facilitator (which did not cover any of the topics in the questionnaire), it is most likely that any changes in the learners view of the topic resulted from something that happened during gameplay or, at the very least, was part of the discursive element associated with gameplay.



**Figure 5.2** Graph showing the numbers of correct responses before and after gameplay. The graph indicates that on a ‘per question’ basis, learners improved their responses in 44% of the questions, maintained their original answers in a further 44% of the questions and downgraded their responses in 13% of the questions.

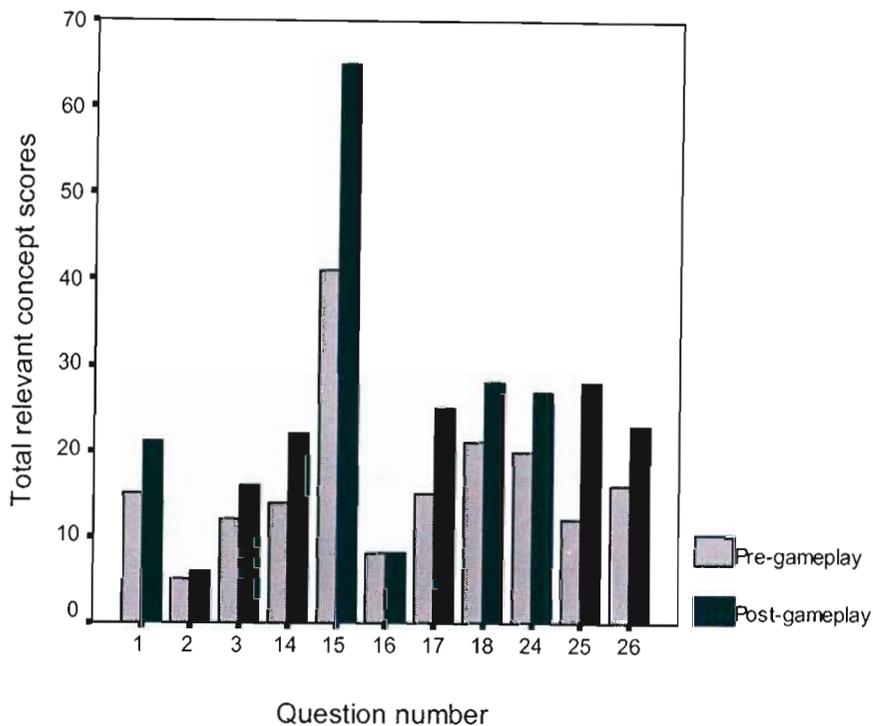
When all questions are considered, the post-gameplay questionnaire was an improvement on the pre-gameplay questionnaire. Furthermore, it appeared that the confidence learners had in their initial answers for many of the questions were boosted after playing the game (Figure 5.3). This is feasible in that if learners were initially unsure about a certain aspect of the content and then what they thought was confirmed either through interfacing with the game environment or through the resultant discourse with their gameplay partner, then their confidence in their answer would either remain the same or likely increase after gameplay. This change in mean confidence between pre- and post-gameplay questionnaires is apparent when comparing the two samples.

The trends shown in both Figures 5.2 and 5.3 indicate that learners are taking something away with them after playing the game. Since determining whether this occurs, and to what degree it may occur, is beyond the focus of this study, one cannot state conclusively, nor backup these assumptions with empirical statistically robust analyses, as to what degree of learning is taking place. Suffice it to say that the trends indicated in these results suggest that learners firstly get more questions correct in the post-gameplay questionnaire when compared with the pre-gameplay questionnaire and that learners appear to be more confident of their answers in the post-gameplay questionnaire. These trends certainly indicate that learners might learn something from gameplay or that gameplay is effective at validating their pre-existing knowledge concerning certain topics.



**Figure 5.3** Graph showing the mean confidence levels specified by learners in the pre- and post-gameplay questionnaires. Out of a total of 16 questions, 8 (50%) of the questions were answered more confidently after gameplay than before, and the remaining 50% of questions were answered with the same confidence levels as before gameplay.

When the open-ended questions from the pre- and post-gameplay questionnaires were analysed a marked trend became immediately apparent. When the total relevant concept scores for each question were graphed it could be seen that the post-gameplay questionnaires had substantially higher concept scores than the pre-gameplay questionnaires (Figure 5.4). Furthermore, the pre- and post-gameplay concept scores were subjected to statistical analysis to see if they were significantly different from one another. This was done by means of a Wilcoxon paired signed rank test.

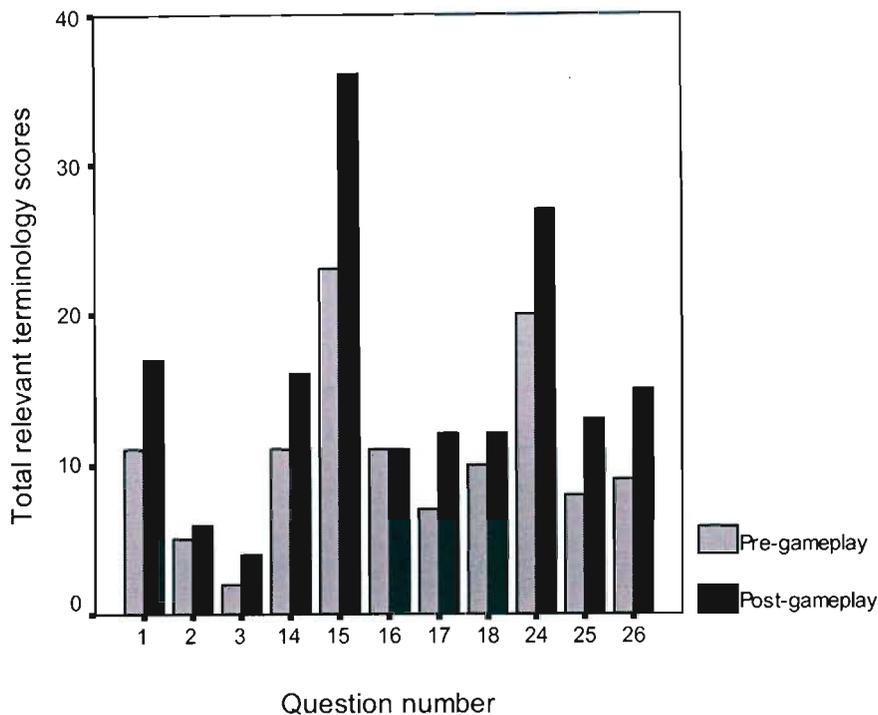


**Figure 5.4** Graph showing the comparison between the pre- and post-gameplay relevant concept scores. The graph shows that the number of relevant concepts included in the learners answers were consistently higher across all questions after gameplay.

The parametric paired samples T-test is a more powerful test but it assumes that the data that it compares is normally distributed and departures from this distribution can cause problems with accuracy. To test the distribution of the concept scores a Kolmogrov-Smirnov procedure was run. This procedure confirmed that the concept score populations were both normally distributed (pre-gameplay concept score:  $P = 0.557$ ,  $N = 11$ ; post-gameplay concept score:  $P = 0.215$ ,  $N = 11$ ). However, the smaller the sample size the less likely a Kolmogrov Smirnov test is to detect the presence of outliers, and it is these outliers that can cause statistical misrepresentations (Zar, 1996). One way to get around this is to do a normal probability plot where the points are plotted graphically and outliers can be visually detected. When a normal probability plot was performed the presence of one outlier was found. Therefore, the Wilcoxon paired signed rank test, which does not assume normal data distribution, was used instead. The results from this test indicated that the post-gameplay relevant concept scores were significantly higher than their pre-gameplay counterparts ( $Z = -2.810$ ;  $P = 0.005$ ). This means that learners consistently answered the open-ended questions after gameplay with more relevant concepts than before gameplay.

In addition, when the pre- and post-gameplay relevant terminology scores were compared the post-gameplay terminology scores were consistently higher across all questions (Figure 5.5). These two data populations

were also compared to see if they were statistically significantly different, and this was done using a Wilcoxon paired signed ranks test. The pre- and post-gameplay terminology scores were determined to be significantly different ( $Z = -2.814$ ;  $P = 0.005$ ) with the post-gameplay terminology scores being higher (mean 10.64) than those from the pre-gameplay questionnaires (mean 15.36).



**Figure 5.5** Graph showing the total relevant terminology scores for pre- and post-gameplay questionnaires. The post-gameplay relevant terminology scores are consistently higher than their pre-gameplay counterparts across all questions with the exception of question 16 which remains unchanged.

These results indicate not only that the learners responded with more appropriate and informed answers after gameplay, but that they were also able to incorporate the relevant terminology into their explanations. All of the open-ended questions here referred to puzzles that were embedded in the portal environment and with which the learners engaged during gameplay. While it is not possible with the data that has been collected here to conclusively attribute this increased learner performance to the interaction with the puzzles, it seems a feasible explanation.

Perhaps criticism could be levied at the author for the manner in which the gameplay testing was run. It might have been more beneficial to ask respondents to fill in the post-gameplay questionnaire an extended period after gameplay and not when their interactions with the facilitator and their gameplay partners were still foremost in their minds. This approach would have been complicated by the simple fact that when learners

leave the testing premises after gameplay they are open to numerous sources of information which would be considered confounding factors in the post-gameplay analysis. In other words, one could never be sure that the change in their knowledge state was a direct result of the learning environment and not some other source.

It is instead suggested that whether increased learner performance is a result of the interaction with the learning environment or whether the puzzle interfaces simply stimulated dialogue between the learners is almost immaterial. What ultimately matters is that learner performance has increased and this increased performance must be due to something that happened during gameplay. These types of environments are appealing to learners and one of their many strengths is that they do get learners talking to one another about the concepts presented in the environment.

### **5.3.3 Learner observations during gameplay**

One of the first things that becomes immediately apparent when reading the transcript of the dialogue between the learners while playing the game is that they tend to discuss their actions and perceptions of the learning environment a lot. In sorting the information yielded for these transcripts it was decided to group the transcripts according to the different themes discussed. Accordingly, five main discussion themes were identified, containing information pertaining to the (1) storyline of the learning environment, (2) HIV lifecycle puzzle, (3) HIV window period puzzle, (4) tuberculosis puzzle, and the (5) cancer puzzle.

Each of these areas of discussion will be examined to identify the kinds of issues that learners discuss when interacting with this learning environment.

#### *Storyline of the learning environment*

The main aim of the burning ground area was to set the scene for the rest of the adventure and to make learners feel that there was some sort of dark undercurrent in the portal and that not all was as it seemed. From the analysis of the transcripts referring to this area, it becomes immediately apparent that all the objectives for this area were met and successfully interpreted by the learners.

All the learners commented on the fact that someone had died (seen from the remains in the fireplace), and some learners hazarded a guess of what they died from. Two of the learner groups speculated that the person had died from HIV/AIDS (due to the presence of the antiretroviral vial in the fireplace) and a further two groups commented that they thought maybe it was a vial filled with poison that killed the person. One group mentioned that the person who died was sick.

When exploring the items in the fireplace all the groups commented that the necklace looked quite ethnic and was two groups linked the presence of the necklace with the dead body, saying that the dead person was a woman and she was the one to whom the necklace belonged. Interestingly enough, without having seen any sign of a village at this stage of the exploration, a number of groups mentioned the word 'tribal', normally associated with small, isolated villages in developing countries. In particular, the necklace in the fireplace was referred to as a tribal adornment.

When asked about the notches on the tree, all the groups except one said they thought the notches might be related to some sort of counting or recording method. Their explanations differed on what they thought was being recorded, with some groups saying they thought the notches counted some sort of unit of time, while others thought the notches counted the number of people who had died.

Overall, the perceptions of the learners in this area closely matched the design objectives for the burning ground. From this it can be concluded that when building environments like these it is important to insert objects with meaning and potentially even a history in the context of the story. This necklace is also important for the resolution of the game in that when a learner enters the storeroom once all other puzzles have been solved, there is a picture of the woman who wore this necklace and an explanation of what happened to her which could give learners some resolution about what in the burning ground.

In various other parts of the portal environment learners are able to meet the characters and 'interact' with them. The characters have been cast in specific roles to enhance the way the storyline for the portal is perceived by learners in the environment. All respondents indicated that Dr Meisner was rude and that he was most likely doing something he wasn't supposed to be as he made it clear he did not want anyone around. Some learners guessed that he was testing HIV on the villagers. Others compared the letter from Carua and the email from Meisner in the doctor's office and concluded that someone was not telling the truth.

Learners were generally happy with the appearances of the sangoma and the village headman. One group volunteered that the headman was in charge of the village because of the traditional head-gear he was wearing. Some learners also commented on the high quality of the sangoma model saying it looked very realistic and added nicely to the storyline. However, the majority of learners expressed difficulty in hearing what the sangoma was saying. This was primarily because the voice-recording for the sangoma was not particularly good, but may also have been connected to the fact that the sangoma speaks in riddles which are harder to follow than normal sentences. A few groups were able to correctly interpret what the sangoma said to them as a warning. The sangoma's message is telling the learner that not all is well in the village and that someone is doing illegal testing there.

Generally, learners appeared to have an excellent idea of what was happening around them in the portal and this confirms again the tight link that should exist between a situated learning environment and the storyline which drives learners to explore and be immersed in that environment. Recommendations for building similar types of environments in the future would be to always start by designing an interesting story that is not too easy to grasp but rather requires some extended play and clue gathering to gain an appreciation of the underlying story. Secondly, to try and make every possible aspect of the game design either contribute towards the resolution of the puzzles or the furthering of the storyline. Both these approaches have worked hand in hand in this portal and the positive response from learners in this regard have validated these design efforts.

### *HIV lifecycle puzzle*

A large portion of the dialogue centred around the HIV lifecycle puzzle interface. This is possibly because it is one of the more abstract interfaces in the game, yet is simple to operate when the learner makes the connection that the animated sequences are part of a lifecycle. For some learners this process happened fairly quickly, but for others the connection between sequences was unclear. If groups appeared to be overwhelmed with the interface the facilitator would initiate a conversation regarding the puzzle and try and get learners to think in different ways about what the solution to this puzzle might be. All the groups finally realized it was the HIV lifecycle in the human body and all groups managed to solve the puzzle without the help of the facilitator. One thing the facilitator did have to do was inform learners that there were other resources in the office area where they could read up on some of the issues faced in the puzzle. One group volunteered that they found the diagram of the lifecycle on the blackboard in the office most useful and that they had drawn from that to help solve the puzzle.

All of the groups discussed amongst themselves what the puzzle was about and what the meaning of the sequences was. Some learners even entered into a narrative for the benefit of their gameplay partners describing what was happening at each stage of the HIV lifecycle animations. Furthermore, many learners used formal descriptions of the organisms shown in the puzzle, for example 'lymphocyte'.

When asked for feedback on the puzzle interface some learners indicated that the stages of transcription and translation were hard to follow in the initial sequences, primarily because these events were taking place in a small area of the screen. However, three groups did comment that upon resolution of the puzzle, the zoomed in animation that played was good because it showed the elements of transcription and translation much larger and therefore it 'made things clearer for' the learners.

The HIV puzzle interface yielded the greatest amount of dialogue amongst the puzzles and seemed to be of high interest value to the learners. The puzzle appeared to be generally well understood as all groups were capable of solving it, and it yielded rich information concerning the lifecycle of HIV in the human body.

#### *HIV window period*

The HIV window period puzzle interface was the next most spoken about puzzle while engaged in gameplay. Numerous design concepts went into the design and implementation of this interface and when learners were probed to see if they knew what the puzzle required them to do, all of the design concepts came to the fore.

All of the groups realized that the puzzle interface had two major design themes, namely that of time and HIV. Most groups realized that the time theme was related to months (because of the lunar cycle), and a few of the groups tied the concept of the window period to this puzzle. Some other groups thought the puzzle would address the length of time taken for HIV to degenerate into the AIDS condition. In order to help the learners exploring the environment in future, it was decided to insert a visual clue in the book (inside the Doctor's office) where learners can read up about the HIV window period. The clue would take the form of one half of an old torn photograph showing a small portion of the window period puzzle interface.

Generally speaking, learners took some time in coming to the conclusion about what the puzzle interface was asking for, indicating that perhaps it is too abstract. All learners did finally understand the concept, but some learners required probing questions from the facilitator before making the connection. Also the problem of where to click to activate the puzzle number panels caused initial confusion with learners, but through continuous exploration all learners managed to find the way to operate the interface.

#### *TB puzzle*

Learners appeared to have mixed feelings about this puzzle. One learner's reaction was that if learners weren't science students they would not be able to complete the puzzle, yet other learners appeared to catch on relatively quickly what needed to be done to complete this puzzle. Learners did find this puzzle quite difficult to manipulate at first but soon appeared to settle into the routine of selecting objects, placing them in the inventory before then placing them back in the scene at a later stage.

The presence of the wording "sputum slide" on the slide used in the puzzle prompted two groups to comment spontaneously that the puzzle had something to do with TB before they'd had an opportunity to read the staining instructions.

Because of the complexity of this puzzle with being able to pick up and store items in your inventory, learners found the interface a bit harder to come to grips with. However, when the puzzle was solved and the final slide with stained TB on it could be seen under the microscope, learners commented that the microscopic image of the TB bacterium was a nice touch. Some groups also commented that they liked the tuberculosis book and found the information inside the book most useful.

### *Cancer puzzle*

The cancer puzzle interface was probably the most familiar interface for the learners as it was designed to be solved like a crossword puzzle. All groups identified the need to answer the questions on the bottom panel by clicking on the relevant letters. Interestingly enough, despite this acknowledgement, three players still attempted to solve the puzzle by answering the question with the correct term, but they tried to select the appropriate letters from random locations across the crossword board, and not as parts of words as in a traditional crossword puzzle. Other complications that arose from this interface were that learners did not make the association between the number of blank dashes ( \_ \_ \_ ) and the letter count required for words that needed to be sought out and entered. The result of this was that some learners spent longer than necessary looking for all manner of word combinations in order to answer the question.

### *Linking puzzle performance to learners dialogue interactions*

What has been elucidated thus far is that learners fared better in post-gameplay questionnaires than they did in their pre-gameplay counterparts. It is also known that these learners engaged with the puzzle interfaces while playing the game and in most cases entered into a dialogue with their gameplay partner concerning what they needed to do to solve the puzzle. It can also be seen that some questions show a larger increase in relevant concept score than others when comparing pre- and post-gameplay questionnaires. What isn't known is possibly why there is a marked difference in the magnitude of the relevant concept score increase when moving from pre- to post-gameplay situations.

In an effort to discern the possible role the puzzle interfaces had in this increased learner performance, the audio feedback from the gameplay session was categorized into 7 discernible parts, each closely associated with a particular puzzle interface. The length of the dialogue pertaining to each of these puzzles was then compared to the post-gameplay increase in performance for that puzzle.

The length of the audio tape interactions was not quantified on a time basis from the original audio tape because brief moments of dialogue could be interspersed with punctuated silences, thereby making it difficult

to ascertain exactly how much time was spent discussing a puzzle. Rather, what was decided upon was an empirical analysis of the transcribed dialogue interactions. The number of words spoken with regards to a puzzle interface was taken as a more accurate measure of the length of the dialogue concerning that puzzle. However, the material for some of the questions that were asked in the questionnaires was not available in any one particular location, neither was it associated with any one puzzle interface. An example of this would be the resources showing the differences between bacteria and viruses. Although models and images of both these organisms are placed in three different areas in the portal, learners are not required to physically manipulate a puzzle interface and, through not having to do this, do not find the need to justify their puzzle solving strategy to their gameplay partner. Therefore, information that was not located in a puzzle mechanism typified by the puzzle process model was not included in this analysis simply because the audio interactions do not exist.

The dialogue lengths and the increase in relevant concept scores in post-gameplay questionnaires for seven puzzles were compared. A Wilcoxon signed ranks test correlation was performed on these two data populations to indicate whether the length of the dialogue concerning a puzzle was proportionate to the richness of information learners provided in a post-gameplay situation. The length of the dialogue interaction concerning a puzzle was found to be significantly correlated to the post-gameplay increase in the richness of the response concerning that puzzle (Wilcoxon signed ranks test:  $Z = -2.371$ ;  $P = 0.018$ ).

This significant correlation indicates that the amount of time learners spend conversing and negotiating possible outcomes with their gameplay partners and the facilitator over a particular puzzle might directly translate into that learner's richer understanding of the principles being addressed in the puzzle. This is a result we would expect because one of the whole underpinnings of social constructivism is that people construct their own knowledge of the world around them through social discourse with other people (Savery and Duffy, 1995). von Glasersfeld (1989) stated that sometimes other learners hold alternative views which challenge our current views and therefore serve as the source of puzzlement that ultimately, through the process of negotiation, stimulates new learning.

These results suggest that aside from the degree of immersion these environments are able to achieve, perhaps one of the major strengths of these environments is that it encourages learners to engage in social dialogue both with their peers and with the facilitator. From direct observations conducted during learner gameplay it was noticed that this social dialogue and negotiation process forms a key part of the construction of new knowledge. Learners would typically debate the merits of a problem-solving strategy and then justify their motives and expectations for following that strategy. Also, an important part of the process would be in the social dialogue that followed their attempt at solving the problem. Here learners typically reflected on how

either their strategies had yielded the expected outcome or why they thought the expected outcome had not been achieved. Through this metacognitive aspect of their reflection and the resulting negotiation between gameplay partners, learners appeared to have gained a deeper appreciation for the topic covered in the puzzle process.

#### **5.3.4 Post-gameplay interviews with the learners**

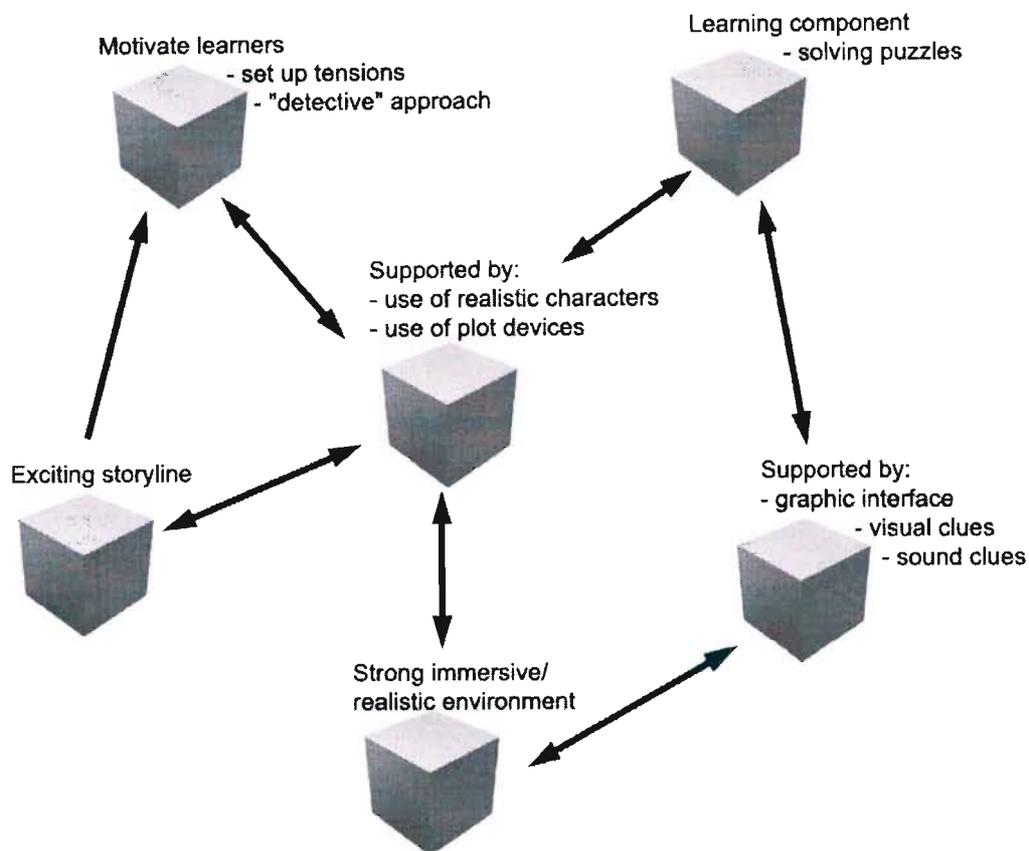
As a summative function after gameplay learners were asked a few questions about their experience of the learning environment. They were asked to give their opinions of what they had seen and to volunteer any information they would deem important in the future refinement of this portal.

Learners gave very complimentary feedback with a number of learners commenting on the high standard of realism in the learning environment (Figure 5.6). One group commented on the clever way in which background cues are given in the portal. Specifically, this group was discussing how you can see where you can move by the placement of the grass (“path is clearly marked”) and how visual clues are given to show the learner that there is still more of the portal to explore. The group was commenting specifically on how you could see the village in the background when exiting the lab area (“It’s clever how when you walk out the lab you see an opening in the grass hinting where you should go next...”).

The interface navigation itself was seen as intuitive by the learners and no major difficulty was experienced by learners in this regard. One learner stated that once you had figured out how to move with the mouse and how to zoom into, and exit from, different views of objects that the rest of the navigation was easy. She did specify, though, that perhaps some instructions at the outset of the game on how to manoeuvre through the environment would be useful.

Learning within the context of the portal was supported by the realistic environment in which the puzzles were situated. The illusion of reality and context helped learners buy into the puzzle process more readily and promoted exploration of the environment. The information content in the Doctor’s office was described as ‘really informative and understandable’. The puzzle interfaces were described as fascinating and one respondent went as far as to say that the trial and error approach to solving the puzzles was a very good idea and it got him to think about the concepts a lot more closely. Another learner group showed excitement at the way the clues were dispersed throughout the game environment because they saw their role in solving this mystery as being akin to that of a detective – reading clues, meeting characters and then piecing everything slowly together to unravel the main mystery. Some learners stated explicitly that in their opinion they had learned so much from their interactions in the portal (“You learn a lot from this game”) and others

commented on the way in which the support material complemented the puzzle process (“the diagram on the board in the Doctor’s office was very helpful [for solving the HIV lifecycle puzzle]”).



**Figure 5.6** A concept diagram showing general themes evident in the post-gameplay interviews. Learners found that the exciting storyline motivated them to play the game while the use of realistic characters, plot devices and a realistic interface heightened their sense of the adventure. Learning was supported by the inclusion of the puzzle interfaces and these puzzles were ‘supported’ by the realistic environments in which they were situated.

The characters in the portal were seen by learners as being realistic (“the sangoma is excellent! She is so realistic – the eyes, expression and wrinkles...”), and the plot devices used in the portal such as conflicting views of the village headman and the sangoma contributed significantly to the learner’s perception of an evil influence in the portal (“someone is not telling the truth...”). A number of learners commented on the warning given by the sangoma as being clever and well contextualised in the portal setting (“Dr. Meisner is the snake she was talking about...the use of snakes as being evil is pretty well suited to the culture.”), while others commented on the subtlety of the cryptic clue the sangoma gave (“oh, so she’s talking about a ‘secret room’. There must be somewhere we must look to find out more.”).

Learners also commented that the music propagated certain tones within the different areas of the game and that these tones furthered the sense of immersion. The music in the burning ground area was described as being suspicious (“the music implies something unusual has happened here, something suspicious”) while the music in the medical tent was noted as ‘eerie’ (“that music was quite eerie and gave me an uneasy feeling”).

Finally, some learners openly commented that this game was unlike any other game they’d ever played (“This is very different to any other computer game because you have to think. This is really cool.”) while others commented that they would have benefited from playing such a game instead of having the routine lectures to which they were subjected (“This is so cool. It would have been great to do this in lectures. It would have made things a lot easier to visualize like the lifecycles as opposed to pencil scribbles on paper”). When asked if they would change anything if given the opportunity the learners said that the environment was suitable as it was (“Honestly, I would not change anything in the game”).

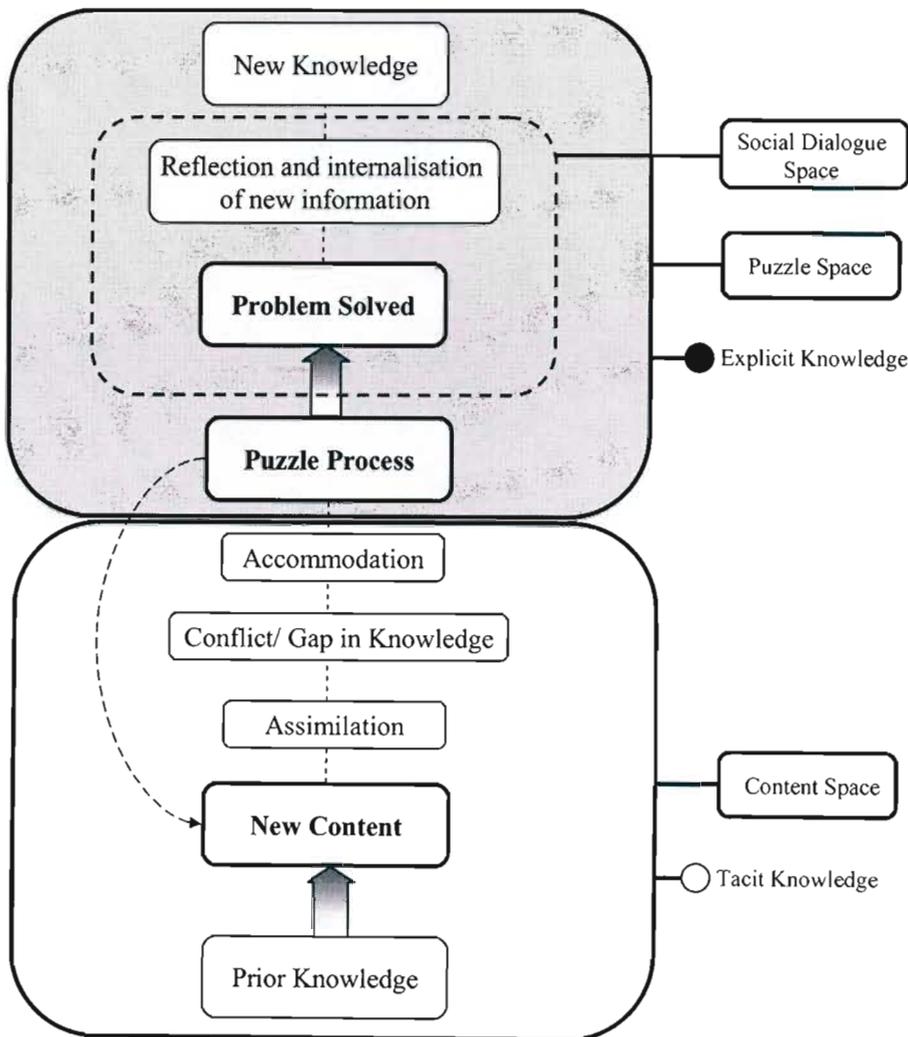
None of the learners had any major difficulty with moving around the portal, coming to grips with the puzzle interfaces or being able to at least make an educated guess at what was happening in the portal. The storyline appeared to be quite well understood simply through taking note of the visual clues embedded in the environment.

#### **5.4 Conclusion**

The formative testing of the interactive learning environment was successful with some interesting results. Firstly, the learners appeared to take something away with them after interacting with the game environment because they supplied answers that were significantly richer in feedback than their pre-gameplay questionnaires. This increased level of richness in post-gameplay questionnaire responses appeared, at least tentatively, to be linked to the amount of dialogue that was entered into during gameplay concerning a puzzle interface. In this case, here would be an example of the puzzle interface providing the learners with cognitive puzzlement, thus encouraging them to seek help, find resources or negotiate amongst themselves a meaning for the puzzle interface. Through the mechanism of positive feedback the puzzle confirms the correct strategy when it is attempted by the learners, thus cementing the associations in their minds. The puzzles also proved effective as reflective devices because often in the process of testing, especially when learners were communicating with the facilitator after the fact, the puzzles were used as a reflective tool. Learners often resorted to trying to work out why certain approaches hadn’t and other approaches had worked.

But above all, the most noticeable efficacy of the interactive learning environment was that it promoted discussion between learners who would usually not converse on such issues. The theme of social dialogue

between learners appeared to have carried significant weight and was one of the key mechanisms utilized for the construction of novel knowledge. With the realization that these types of environments have powerful associations with social dialogue the original Puzzle Process model (Amory and Seagram, 2003) was modified to incorporate a social dialogue space (Figure 5.7). This social dialogue space makes explicit the need to incorporate social mechanisms of negotiation into the puzzle solving process. When learners discuss their expectations from a particular puzzle solving strategy prior to solving the puzzle, and when they discuss their reflections on the puzzle process that was observed after engaging with the puzzle interface, then the process of internalization is facilitated. Hence it can be seen that the inclusion of this social dialogue space is essential to the model for the development of future game puzzles.



**Figure 5.7** The proposed revision of the Puzzle Process model. This model takes into account the crucial role that social construction and negotiation plays when forming deeper knowledge. Learners use social dialogue as one of the means to negotiate the solving of the puzzle interface and thereafter engage in reflective and even metacognitive social dialogue. This dialogue aids the process of internalisation.

Through the interaction with the puzzle interfaces, the incorporation of the exciting storyline and the embedding of visual clues throughout the game, a rich and integrated learning environment was created. Learners enjoyed the interface, felt it was easy to navigate through the environment and felt the game was beneficial.

## CHAPTER 6

### DISCUSSION

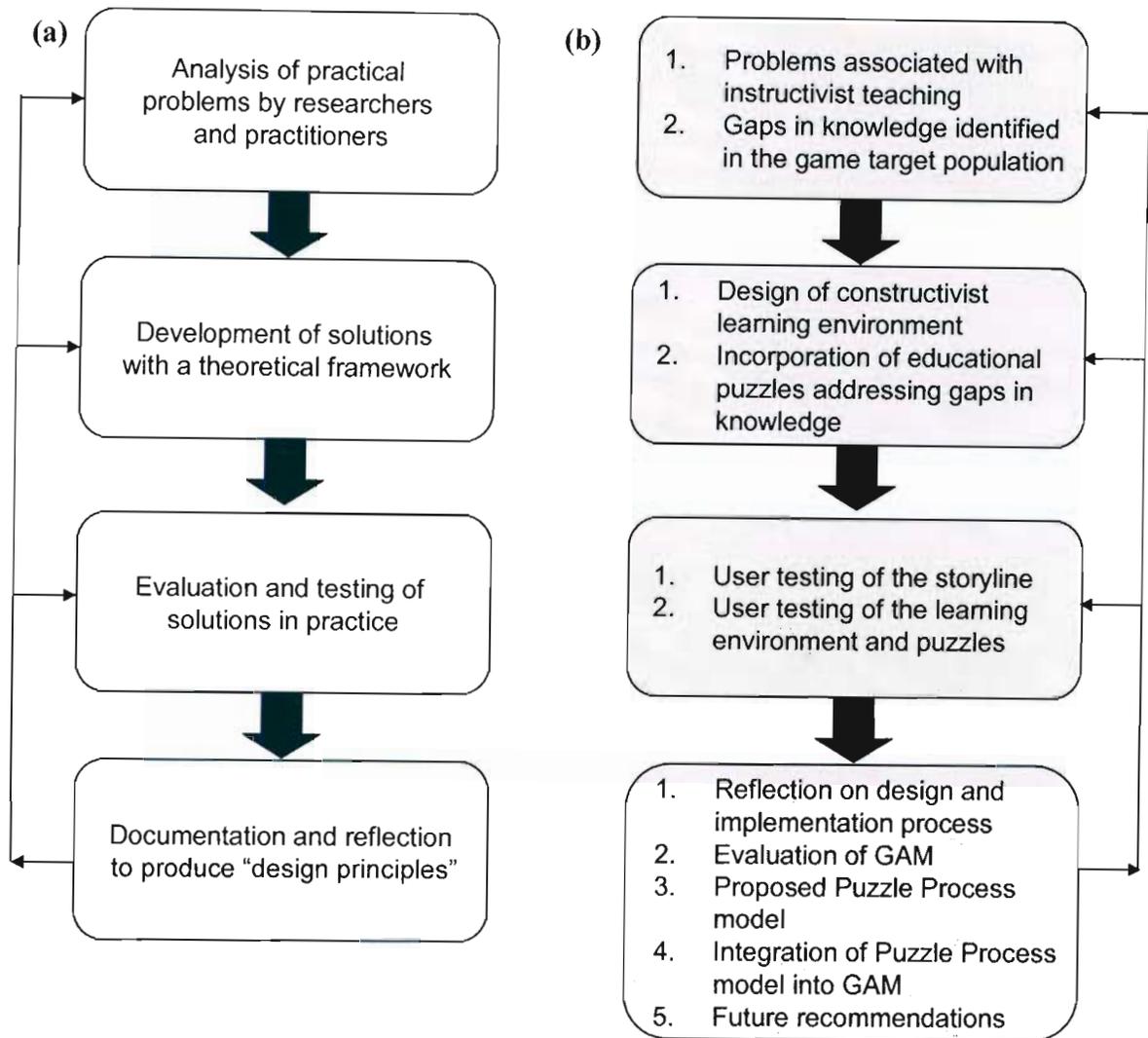
Two key issues were identified as the foci for this study. The first was congruent with a more practical approach to enquiry and entailed the research and design of a 3D microworld environment wherein learners could learn about diseases important in the South African context. The second major focus of this research was the evaluation of the Game Achievement Model and its effectiveness as a tool to be used in the creation of educational environments and as a conceptual framework for the design of educational puzzles. Because of the close manner with which this study corresponded to the development research model (van den Akker, 1999) each stage of this study corresponds directly to a stage of the development research methodology (Figure 6.1). The major findings of this study will be discussed here in the context of the development research model and linked to the greater body of literature concerning these learning environments. Furthermore, from the design experience that resulted from this study, more generalized design principles and the merits for future implementation of these principles will be discussed.

#### 6.1 Analysis of practical problems

##### 6.1.1 Decontextualised learning

A central criticism of widely practiced (instructivist) teaching methodologies is that information is presented to the learner in a decontextualised and inert manner (Choi and Hannafin, 1995). Curricula are regarded as lists of tasks to be completed instead of building blocks of interesting information that all fit together, similar to a mosaic, giving learners a glimpse of the interrelated world in which we live. Learning knowledge in an appropriate context would make learning more enjoyable and more effective with potential long-term improvements in recall ability. Furthermore, the closer the relation of an activity or knowledge domain is to the context from which that activity derives its' meaning, the more likely learners are to recall that information when it is needed (Carraher *et al.*, 1985). Chapter 1 provides a more indepth review of prominent educational theories, their strengths and weaknesses, and how technology can work with these theories and contribute positively to education.

As part of a possible solution in addressing the didactic nature of formalized educational practices, a constructivist educational learning environment was designed. This environment took the form of a virtual reality fully immersive educational adventure game or 'portal'.



**Figure 6.1** Parallels between the (a) development research methodology and (b) the research approach taken in this study.

### 6.1.2 Disease information

Diseases that are relevant to South Africans were chosen as the learning material for this portal. A literature review revealed existing levels of knowledge regarding these diseases in the general population and, based on this information, a questionnaire was drafted, piloted and then distributed to a sample of learners representative of the Science and Engineering faculties at the University of KwaZulu-Natal, Durban.

The results of this survey indicated that while learners were generally aware of the routes of transmission of these diseases, they were largely unaware of the biological entities responsible for causing these diseases. Furthermore, knowledge of prevention for these diseases was often inadequate.

The lowest areas in the performance measures were identified as gaps in knowledge concerning these diseases. Hence, the learning objectives for the portal were defined as:

- the transmission, biology, symptomatic expression and prevention of HIV, malaria and tuberculosis;
- the biology and mechanism of cancer; and
- the exploration of viruses, bacteria and protists, with special focus on the differences between viruses and bacteria and the role of protists in malaria.

These gaps in knowledge in the learner population were addressed by the learning objectives of this study. The constructivist learning environment would therefore encourage learners to construct their own knowledge concerning these areas of disease biology (further details describing the methodology of this survey and the incumbent results can be found in Chapter 2).

## **6.2 Development and testing of solutions within a theoretical framework**

The development of the game environment consisted of two main activities, namely the creation of an appropriate storyline to motivate learners playing in the portal, and the 3D creation of the educational puzzles and the surrounding environment resources.

### **6.2.1 Development and testing of the storyline**

The importance of a good storyline was recognized as a powerful tool for the promotion of intrinsic learner motivation. The Game Achievement Model was used as the theoretical framework against which the storyline was devised and matched to the appropriate learning objectives.

#### *Storyline testing*

This storyline was tested for its suitability in the context of the game and its degree of cultural sensitivity. This was achieved through a survey conducted on members of the target group for the game. Care was taken to include members of all major race groups in this analysis. The analysis of the questionnaire responses showed that the storyline was well suited to the game environment and was seen as an ample form of intrinsic motivation for players to want to play and complete the game. Specifically, the storyline was seen as realistic enough to be believable, but contentious enough to motivate the learners with the promise of real personal satisfaction at having stopped the illegal testing inherent in the story.

In addition, the use of characters was seen as realistic and as contributing toward the illusion of reality. While some stereotypes were necessarily left intact to make the storyline more believable, the majority of stereotypes were broken, thereby making the game more acceptable across a wider range of cultural influences. Chapter 3 describes the methodology utilized, and results obtained, with regards to the testing of the storyline.

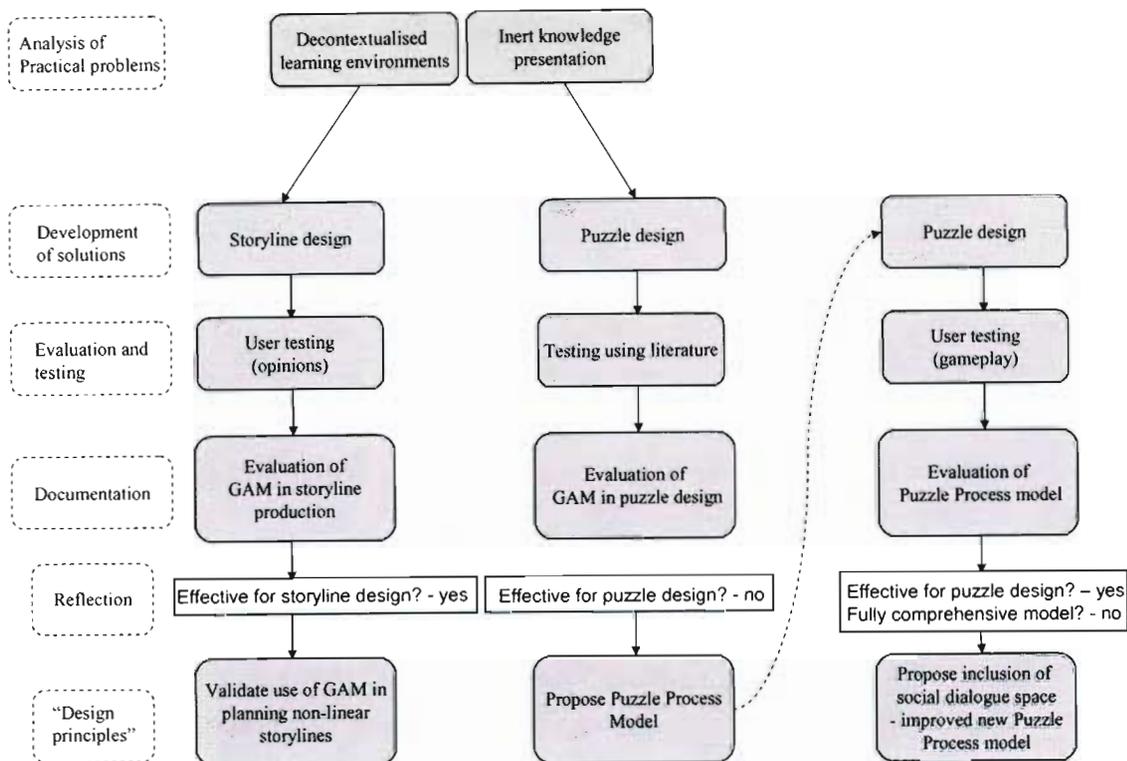
### **6.2.2 Evaluation of the Game Achievement Model**

As part of an iterative cycle of formative evaluation (Figure 6.2), the GAM was evaluated for its effectiveness as a guide to the design of these types of learning environments. More specifically, the GAM was evaluated for its effectiveness in designing non-linear storylines with the story creation team that worked closely with the model, while the effectiveness of this model for the design of realistic storylines was shown through user testing within the target group (for greater detail see Chapter 3). The GAM was followed closely in the design of the storyline for the game portal and proved to be an excellent model for this purpose. Perhaps the most important contribution and strength of the GAM was the manner in which it made the learning objectives explicit to all involved in the storyline design process, even prior to the start of the design process. All members of the storyline design team, even non-experts in the field, had to familiarize themselves with the learning objectives at the outset which enabled all members of the team to start with the same background knowledge. The value of this shared understanding was evident in the manner with which the storyline comprehensively encompassed all of the learning objectives.

The reductionist nature of the GAM framework provided the necessary degree of flexibility in the storyline design process. Learning objectives were broadly defined at the act level, and not the more restrictive individual scene level, thereby allowing effective puzzle design that could span a number of different scenes within each act. This was an advantage as it allowed the designers to incorporate a sense of continuity between different puzzles and shared knowledge domains. This type of continuity is important for the emphasis that the knowledge gained in the portal environment is not isolated, but links to an entire body of knowledge, and can be used in many different real-life situations. This movement away from the presentation of inert information is an important outcome of contextualised education environments.

The complex task of writing a non-linear storyline is often badly executed. This is because of the inherent difficulties of scripting a story with multiple possible outcomes. The GAM was described by those involved in the storyline design as being instrumental in the conversion of a linear storyline to a non-linear storyline. This was partly due to the explicit manner in which the learning objectives were highlighted by the model as well as the model's ability to assist designers in arranging their thoughts. All members involved in the design

process expressed the feeling that had it not been for the GAM, their thoughts on the requirements for the merger between the storyline and the learning objectives would not have been as structured or as relevant as they were.



**Figure 6.2** Iterative stages of development research for individual components of the study. The development of this portal did not follow a strictly linear approach, but much of the process was iterative with one concept giving rise to another before being tested and either confirmed or refuted.

The GAM also assisted the designers in their ability to envisage and adequately describe the characters in the portal. Because of the explicit statement of the learning objectives, designers were aware of the role each character had to play in the realisation of the learning objectives and could use this information to help define the disposition, mannerisms and physicality of the characters. This information was instrumental in the construction of dialogue interaction manuscripts for each character.

One of the problems with the GAM was that the storyline designers found it conceptually difficult to understand fully. This problem was circumvented by the explanation of, and constant reiterative referral to, the model during the definition of the learning objectives. Once the model was understood by those members involved in the design process, the benefits of the theoretical framework began to manifest.

A second, and perhaps more influential, problem relates to the reductionist approach to the definition of the puzzles within the GAM. It was noted that the design of puzzles using only the definitions inherent in the GAM was a difficult, ill-defined task. While all of the interfaces defined by the model (Figure 1.2; p. 20) for the puzzle creation hold true and need to be considered in the puzzle design process, this approach was found to be too simplistic to adequately describe the puzzle creation process. As a consequence, it was difficult to design appropriate puzzles based on this model.

### **6.3 Reflection and definition of design principles**

#### **6.3.1 Puzzle Process model**

In order to fulfill this need, a new model was proposed. This model was called the Puzzle Process Model (Figure 4.7; p. 95) and describes two distinct spaces within the puzzle realm. The first area, the content space, is defined as the area where new information is presented to the learner, and where puzzlement and conflict occurs in the cognitive structures relating to that knowledge domain. In the context of this portal, new content is presented to the learners either in written or verbal form. Written information can be accessed by learners in books, posters, via email or over the Internet. Information from any of these sources needs to be assimilated such that a resultant conflict in the learner's cognitive structures is generated. Subsequently, this conflict needs to be resolved through the process of accommodation. Following this process, the learner is in a position to advance into the puzzle space of the puzzle process model. In this space the learner interacts with components of the puzzle, usually manipulating the puzzle and obtaining feedback from these actions. This process of manipulation and resultant feedback, or reinforcement, serves to encourage the learner to think about the puzzle process and to further understand the implications of the recently accommodated information on this puzzle process. By correctly superimposing the appropriate content onto the puzzle process, learners can link concepts and reinforce what they have just learned.

Tacit knowledge can be described as knowledge which has not been analysed while explicit knowledge is the outcome of reflection (Rieber, 1996a). This puzzle process aids learners in the transformation of tacit knowledge, through reinforcement and reflection, into explicit knowledge.

The real strength of the puzzle process is evident when, proceeding the successful resolution of a problem, learners are encouraged to reflect on the entire process and even on the strategies that were used to solve the problem. Confirmation that the method used by the learner to solve the problem was correct serves to reinforce the recently accommodated knowledge, thereby facilitating deep learning in the learner and the corresponding transfer of tacit knowledge into implicit knowledge. Another major strength of this component

of the process is that learners are encouraged to consider and examine the strategies used in the resolution of the problem. This kind of metacognition serves to enhance the learner's understanding of the concepts being dealt with. Reiterative review of problem-solving strategies should ultimately help the learner improve their problem-solving skills over time. This task is of paramount importance because of the extensive applications of problem-solving ability in reality.

### **6.3.2 Conceptual Summary puzzle**

Another important concept not defined in the GAM is the need to link different knowledge domains, or even different aspects of the same knowledge domain, between puzzles. One of the major criticisms of instructivist teaching methodologies is the presentation of inert, contextually sterile information. Part of the reason why it is decontextualised is because it is presented to learners in unnatural, isolated and curriculum-imposed segments that appear to be completely unrelated to any other knowledge domain. To avoid perpetuating a situation where each puzzle was addressing only a single knowledge domain and failing to link the learned knowledge back into the overarching body of knowledge, it was suggested that all the information from puzzles in the portal level be combined in the form of a conceptual summary. A conceptual summary, by definition, requires the information assimilated and accommodated in previous puzzles to be applied to a puzzle process before the final problem could be resolved. Subsequent reflection on the conceptual summary puzzle process results in the integration of the previously learned knowledge into the global knowledge framework. This process allows learners to "see the bigger picture". In order to adequately facilitate this process a model was devised to illustrate the conceptual summary model followed in the design of this portal (Figure 4.8; p. 96).

In summary, the use of the GAM proved to be effective in the design of the storyline. However, whilst the structure of the GAM allowed the learning objectives to be effectively married with the storyline, the way in which the GAM described the design of puzzles was seen as insufficient in its approach. A more explicitly structured model was called for in the puzzle design process. The resultant model described two different spaces, each with a different task in the creation of implicit knowledge from new content and the puzzle process. Furthermore, the GAM did not explicitly state ways in which content areas within a domain could be linked and the formation of a conceptual summary puzzle addressed this concern. The resulting conceptual summary model illustrates the implementation of this concept in the portal.

### 6.3.3 The effectiveness of the Puzzle Process model

When the puzzles, created using the Puzzle process model, were tested as part of a formative evaluation exercise, it was found that the puzzle interfaces were effective at a number of different ‘tasks’. Firstly the puzzles appeared to be successful at encouraging learners to start thinking laterally. This first step relates directly to the layout and design of the puzzle. Puzzle interfaces were designed with strong themes to guide learner thinking about their functionality. Secondly the puzzle interfaces were not well defined to the learners, so cognitive puzzlement could be achieved. In other words, the puzzles are purposefully vague to get learners to communicate with one another to find negotiated ways in which to solve the problem at hand. This seemed to work well in testing as the learning environment stimulated many discussions, many of which were directed at a puzzle interface. It appears from some of the test results that the richness of a learner’s description of a knowledge domain can be positively affected by the amount of social discourse that the learner enters into around that knowledge domain. Through the process of negotiating and constructing shared understandings learners appear to, at the very least, expand their knowledge base of the material concerned. This is a powerful finding and it has implications for the puzzle process model in that this model appeared to facilitate the process of social discourse.

### 6.3.4 The importance of social dialogue

One of the major trends evident when observing the learners during gameplay and during their interaction with the puzzle interfaces was that learners were encouraged to talk to one another and with the facilitator concerning what was happening in the puzzle or the general environment. This trend resulted in rich dialogue interactions between learners, their gameplay partners and the facilitator. It was primarily through this mechanism of social dialogue that many of the learners came to understand the topic in greater detail. In particular, the process of negotiation between learners after solving a puzzle appeared to be a major vehicle for reflection and internalization. Boyle (1997) states that the emphasis should be on authentic tasks and social dialogue to provide a base for experience with the knowledge construction process, and the results of this study concur. Driver *et al.* (1994) contend that social interaction in groups can be seen to provide the stimulus of differing perspectives on which individuals can reflect, and it is through the process of negotiating these different perspectives that learners may attain a richer world view (Savery and Duffy, 1995).

To account for the necessity of this social dialogue, it is proposed that the original Puzzle Process model (Amory and Seagram, 2003) be modified to include a social dialogue space (Figure 5.7; p. 136). The importance of this social dialogue space becomes apparent when learners interact with the puzzle interface and negotiate with one another how to solve the puzzle. Learners typically put forward their argument for

their puzzle solving strategy of their choice before then postulating what they thought the outcome of their strategy would be. Once the puzzle had been solved learners reflected on why their expected outcomes did or did occur. Through this process of reflection and negotiation between learners, internalisation of this information was enhanced.

The new proposed Puzzle Process model is an important contribution in that it provides interactive learning environment designers with a theoretical model on which to base their design efforts. The model clearly defines what interactions should be catered for when designing puzzle interfaces and therefore sets out parameters to be considered in implementing the design.

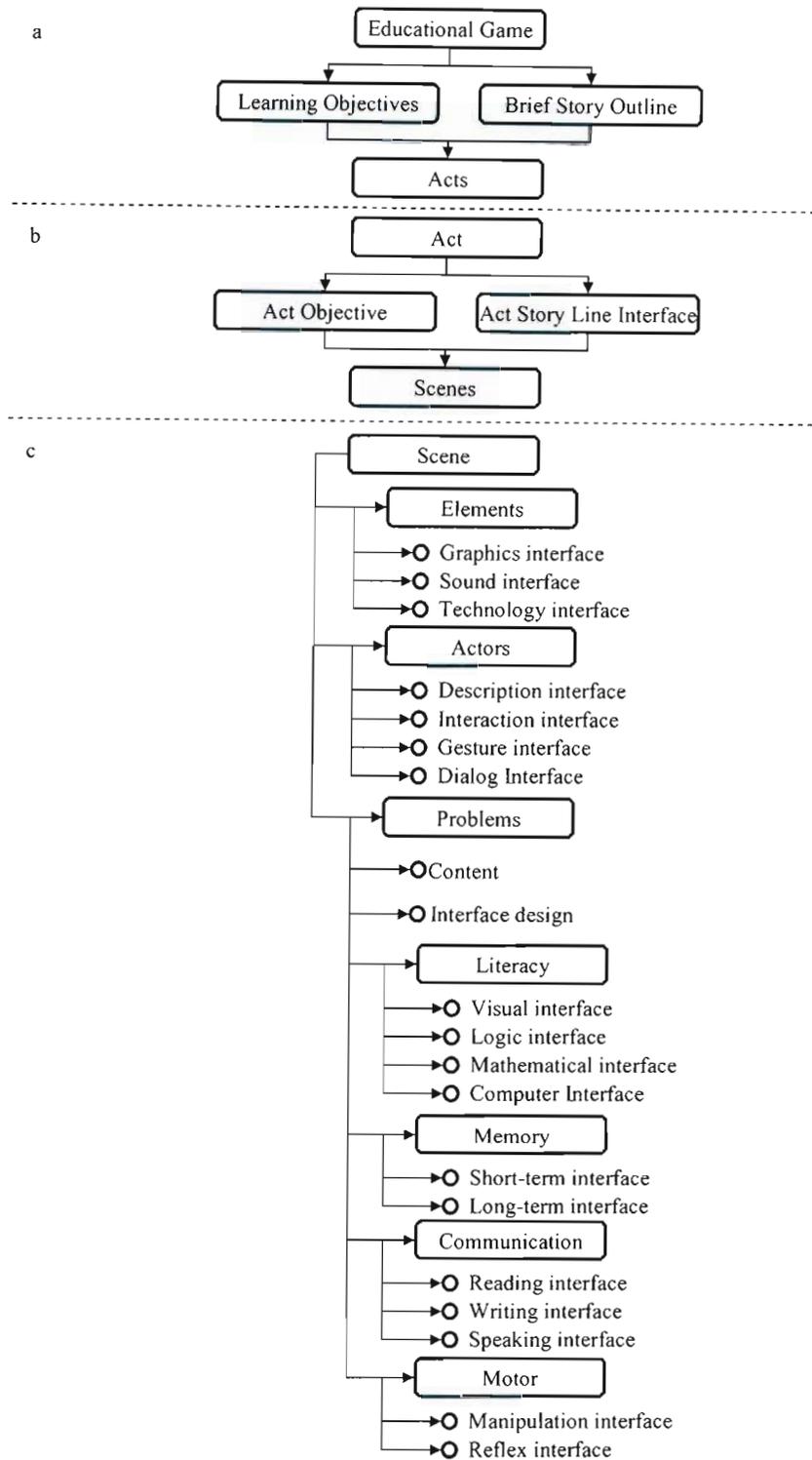
### **6.3.5 Rethinking the Game Achievement model**

The Puzzle Process model was formulated to compensate for inadequacies in the GAM concerning the creation of puzzles for these types of interactive learning environments. However, the Puzzle Process model has no storyline aspect to it at all, since it was designed only with puzzle interfaces in mind. What would be most beneficial to future educational game developers would be a model that encompassed both the storyline development and the guidelines to make explicit what should be taken into consideration when the entire environment is designed. In an attempt to provide designers with such a model, the original GAM was reconceptualised to include the aspects of the Puzzle Process and Conceptual Summary models previously lacking (Figure 6.3).

#### *Content interface*

The inclusion of a content interface as part of the problem space is essential to the success of puzzles in these environments. During user testing it was observed that learners who had not yet found the supporting text for a particular puzzle before attempting to solve the puzzle often became frustrated and disillusioned with that puzzle interface. This kind of reaction could be detrimental to the learning process and should be avoided wherever possible. Upon reflection of this phenomenon it became clear that intricately linked to the design of the puzzle interfaces are bound to be certain assumptions that the designer has unwittingly made. For example, in the HIV lifecycle puzzle, the designer has made the assumption that learners have some concept of what a lifecycle is prior to their engagement with the interface. This may not be the case depending on the learner's prior knowledge.

From this point of view the content space not only pre-empts accommodation of new information, but it also serves to bring learners to the same point of departure before attempting to solve a puzzle.



**Figure 6.3** Revised Game Achievement Model. The revised model incorporates the content and interface design interfaces. These interfaces make explicit the need for puzzle related content to be made available to the learners, as well as the need for the puzzle interfaces to provide strong visual links to the puzzle content and the learner's prior knowledge.

Another advantage of providing learners with this base information before they attempt the puzzles is that they are more likely to engage in social negotiation with other learners if they feel they have some concept of what the puzzle is about. Without this initial information exposure, many learners would most likely feel unqualified to even hazard a guess at what was happening in a lifecycle for instance. If learners were to feel unqualified or ill-equipped to deal with a puzzle, the degree of social negotiation for that puzzle would be diminished. Recht and Leslie (1988) state that, independent of the medium, learners with a high level of prior knowledge consistently out-perform learners with limited prior knowledge. Scott *et al.* (1987) argue that constructivist learning depends not only on the learning environment but also on the prior knowledge, attitudes and goals of the learner.

### *Interface design*

Further to the addition of a content interface, the need for an interface design entity exists. This interface refers to the associations learners will make between a puzzle interface and their prior knowledge. These types of associations would normally be linked to thematic design issues, and use of relevant themes in puzzle design could greatly benefit the learners in their interpretation of the puzzle. An example of this thematic design can be seen in the HIV window period puzzle (Figure 4.11; p. 102). This puzzle interface deals with the length of the HIV window period and is therefore dealing with time (months) and HIV. Accordingly, strong HIV and time themes are brought to the fore in this puzzle interface. The use of 12 moons arranged in a typical clock-face formation, all at different stages of the lunar cycle, suggests a time link while the use of repetitive HIV patterning and the presence of a HI virus in the middle of the puzzle interface suggest the involvement of HIV. When asked about this puzzle interface during user testing, all learners correctly identified HIV and time as being principal components of the puzzle.

This initial identification was instrumental in influencing the learners thought patterns and the way they perceived the puzzle process thereafter. This has important consequences for learning in these environments, especially since the degree to which information is related to prior knowledge is among the most important determinants of learning (Ausubel, 1968). Rieber (1996b) suggests that the degree to which learners can link new ideas to prior knowledge is a measure of the meaningfulness of those new ideas. Savery and Duffy (1995) contend that our understanding is in our interactions with the environment. In other words, if the puzzle interface is sufficiently well designed to allow easy linking of new concepts to prior knowledge then learners are more likely to engage in meaningful interactions with the puzzle interface.

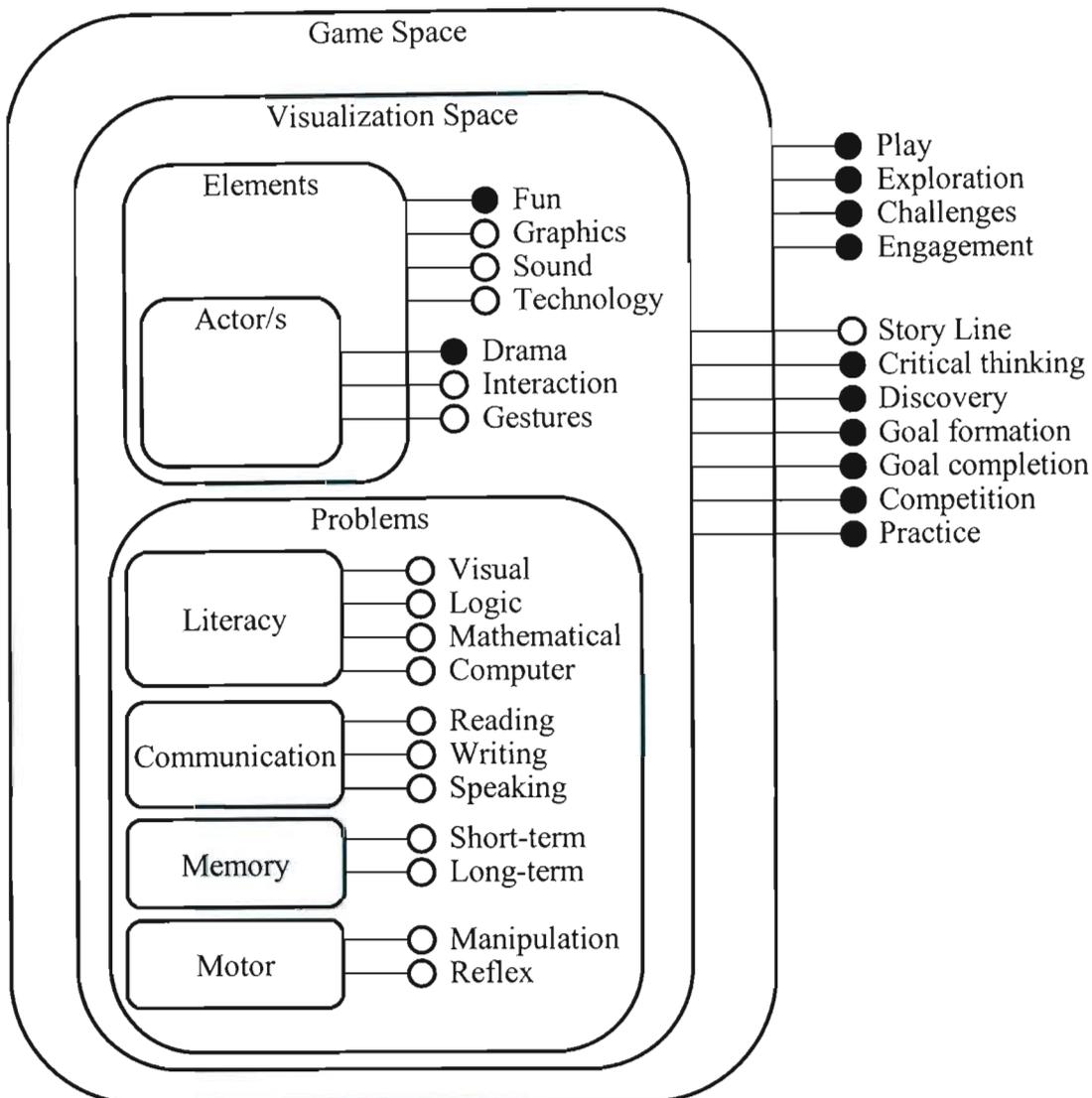
### 6.3.6 Rethinking the Game Object model

In 2001 Amory proposed the Game Object Model (GOM), a conceptual model that marries educational theory and game design (Figure 6.4). The GOM is based on Object Oriented Programming concepts and attempts to reconcile pedagogical dimensions and game elements (Amory, 2001). This model describes a *game space* which, in turn, consists of a *visualization space* and a *problem space* (Amory and Seagram, 2003). Specifically, the GOM describes *components* (represented by rounded squares) that support abstract educational objectives and concrete interfaces that allow the realization of these objectives (Amory and Seagram, 2003). These components may be self-sufficient or part of a parent component, in which case they inherit all the interfaces from the parent component. As an example, in Figure 6.4 the *elements component* is part of the *visualisation space* and, as such, inherits the visualization and game space interfaces as well as those interfaces directly associated with the *elements component*. This model more broadly defines the ways in which games should be based on pedagogy whereas the Game Achievement Model rather defines more specifically how such games can be designed. However, because the GOM is the model from which the Game Achievement Model was derived, it is necessary to update this model in light of the changes that have been proposed to the GAM.

As a direct consequence of the addition of a *content interface* and *interface design interface* to the Game Achievement Model, these new interfaces were defined as an important part of the Game Object Model. Specifically, these concrete interfaces were added to the *problem space* component (Figure 6.5). It can now be seen that the presence of appropriate content and interface design for the problem space aids in the achievement of a realistic storyline, critical thinking, discovery, goal formation, goal completion, competition and practice. All these interfaces, in turn, allow for the realization of more general abstract interfaces such as play, exploration, challenge and engagement (Figure 6.5). The addition of appropriate content as well as appropriate interface design helps the puzzles integrate more holistically into the entire game space.

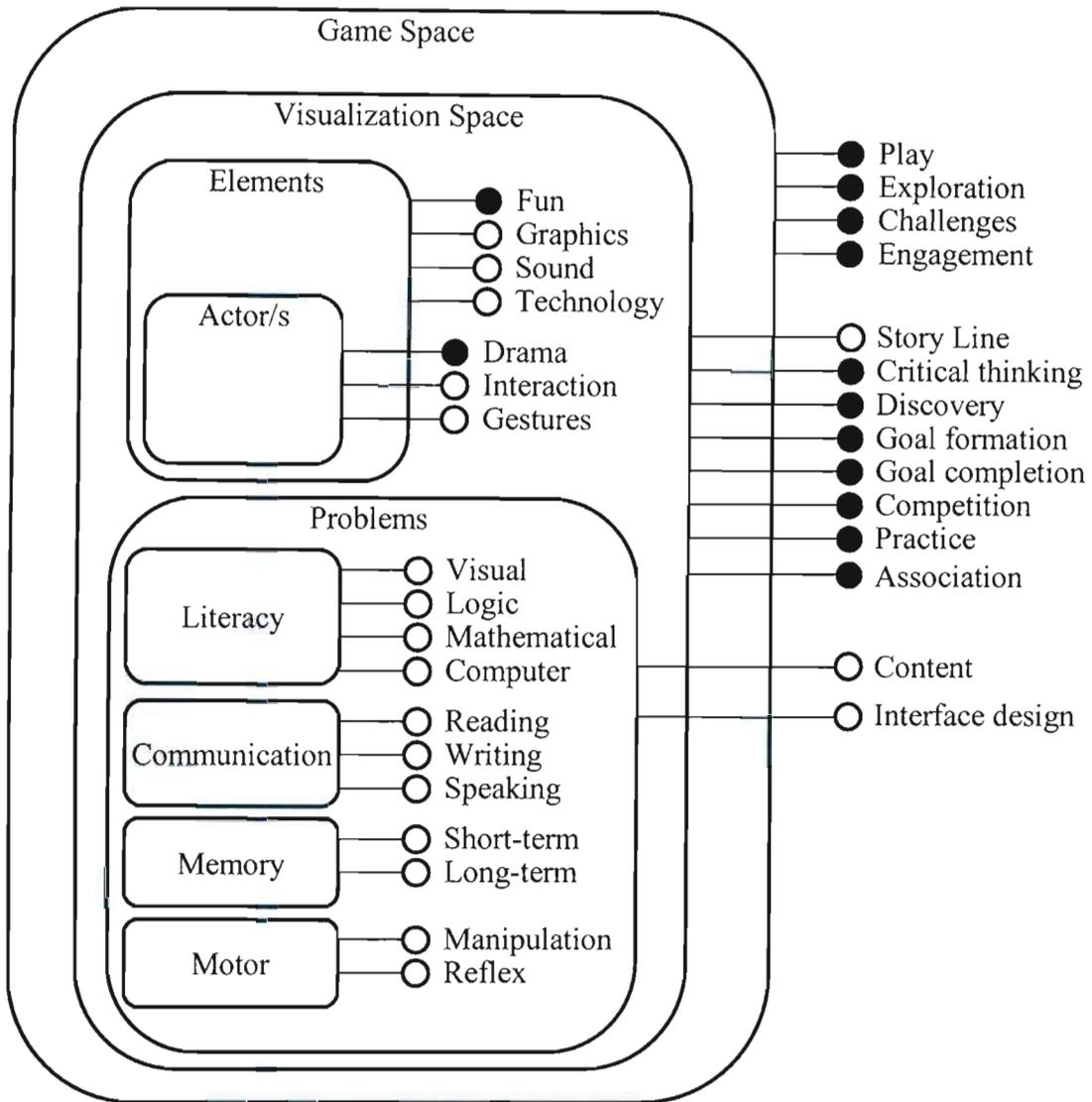
#### *Association interface*

The findings of this study promoted one further reconceptualisation of the GOM, namely the addition of an *association interface* (Figure 6.5). This interface is described as an abstract interface for the visualization space, and specifically refers to the way in which puzzles within the visualization space should associate with one another. This association is a particularly important as it promotes the linking of different puzzles and different knowledge domains within an environment.



**Figure 6.4** Visualisation of the Game Object Model. The black circles (●) represent abstract interfaces while the white circles (○) represent concrete interfaces. The outer interfaces are realised through the incorporation of the inner interfaces and components. Taken from Amory, 2001.

The reason this is seen as being important is because a piece of knowledge can only really take on its true value when viewed in context to the information related to that piece of knowledge. Numerous authors have argued for the need to contextualize information (Herrington *et al.*, 2004; Reeves, 2002; Boyle, 1997; Rieber, 1996b; Fosnot, 1996) and the careful planning of puzzle interface associations can further the contextualization of the information being presented. An example of this concept comes from the conceptual summary puzzle in the portal. The main purpose of this puzzle is to link the major concepts in the portal. By solving this puzzle, learners are expected to place the information they have gathered into a wider frame of reference that is not restricted simply to the puzzle interface itself. In other words, learners are encouraged to see the 'bigger picture'.



**Figure 6.5** The revised Game Object Model. This model includes the addition of an abstract association interface linked to the visualisation space. In addition, the need for content inclusion and appropriate interface design are made explicit by the addition of the content and interface design interfaces associated with the puzzle space.

### 6.4 Constructivist processes

In addition to the game portal and the analysis of existing theoretical models used in the design process, the importance of this study also lies in the process that was followed in the realisation of the game design. Constructivist learning principles are indeed very powerful tools that can be used beneficially in almost any environment.

Everyone involved in this study was, at some time during their involvement, engaged in a constructivist learning environment. The story workshop was a prime example of how different people could negotiate common ground as well as learn about one another through the process of social discourse.

In many other areas of the game design, for example the 3D graphic realisation of the gaming environment, knowledge was continually being constructed and mutual understandings negotiated between those involved in the process. An example of this was in the design of the puzzles themselves. In order to adequately design a puzzle that would stimulate learner engagement, it was necessary to form a deep understanding of the problem that the puzzle would address. Grabinger (1996) makes a valid comment in that it is ironically those who design the educational material for teaching that learn the most. This is the type of understanding that results from reflection on the material. The real strength of the puzzles lie in the fact that they, too, can draw the learner into a situation where they are compelled to start thinking more deeply about the subject matter at hand. By so doing, they encourage learners to reflect on the puzzle process and form long-term associative links.

## **6.5 Conclusion**

In conclusion, not only was the creation of the game a beneficial part of this study, but the entire process was an extremely rich learning opportunity. Numerous theoretical models have been reviewed for future use in the designing of virtual learning environments, including the Game Object model, the Game Achievement model, the Puzzle Process model and the Conceptual Summary model. All these models make an important contribution to the design and conceptualisation of interactive learning environments. The methods employed in the design of this portal have also been discussed, with key issues in the design of puzzle interfaces being brought to the fore. Furthermore, the learning environment was subjected to user testing and the analysis indicates that learning environments such as these may be powerful tools for learning. This type of situated learning environment is ideally suited to 'learning by doing' and learning through social discourse, and the puzzle interfaces for the game were designed to be perfectly suited for these purposes.

The use of constructivism formed a core part of this research with every step undertaken in this project being a social collaboration of sorts. The storyline for the portal was socially constructed with a number of interested collaborators from different ethnic and cultural backgrounds resulting in a rich and exciting storyline. The Game Achievement model was negotiated and discussed by the development team that worked closely with it. This model promoted interaction between the members and allowed them to come to a deeper understanding of what was required for the story process. The suitability of the character selections were tested by gauging learners perceptions to these characters. Learners provided input and their views fostered

discussions concerning the characters. The portal itself was designed with much negotiation and review amongst stakeholders involved with the project and this collaboration helped produce the exciting final product. Learners also had an opportunity to provide feedback on the portal and were urged to provide their views pertaining to a number of different issues with the interface design and general impressions of the portal. Perhaps most importantly, though, playing the portal appears to foster a social constructivist environment where learners are motivated and encouraged to discuss their experiences and expectations from the gameplay process. This process of social negotiation positively impacts the information integration and retention for learners, allowing them to yield answers rich in information in post-gameplay questionnaires.

According to the results of this study, it appears that social constructivist learning environments have huge potential as educational environments. Their strength may certainly lie in their ability to encourage learners to discuss various knowledge domains both with their peers and facilitators alike.

## **6.6 Future research**

Full summative evaluation needs to be conducted on this portal. This encompasses the observation of learners in the process of puzzle resolution as well as their interactions with the puzzle interfaces. It might also be necessary to ascertain whether certain learning styles are more amenable to this method of learning, or if it is equally suitable across all learning styles. Furthermore, the conceptual summary model needs to be properly tested with users in the portal environment to see if it is successful in encouraging the linking of concepts from different knowledge domains into a more comprehensive oversight of all the domains concerned. Once the portal is complete a full user analysis needs to be done on a larger sample size to truly elucidate the strengths and weaknesses of these types of environments in education.

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## APPENDIX A

### *Diseases Questionnaire*

*Virtual Learning Space Project*  
University of Natal  
Durban

#### *Introduction*

The Virtual Learning Space (VLS) project is one wherein the learning methods of students are elucidated and explored. The VLS project is currently designing a 3-D virtual world computer adventure game that teaches students about, amongst other things, prominent diseases in Africa. To develop an educational game that will be useful and effective in teaching students, it is necessary to first find out what the students don't know about these diseases.

This is a questionnaire about HIV/AIDS, cancer, tuberculosis and malaria. This is not a test, and by participating you will remain completely anonymous. All you need to do is answer the questionnaire to the best of your knowledge. You will be asked to specify some general information about yourself, namely your age, gender and race. This information is simply used to get an idea of what kind of target group the game is being produced for.

The questionnaire comprises **32 questions**. These questions focus mainly on the causes, the transmission and the avoidance of these diseases. Please answer **all** the questions before handing it back. There is no time limit, but the questionnaire should take you approximately 15 minutes to complete.

Thank you for your time.

Rob Seagram  
VLS Project  
University of Natal  
Durban.

#### **Instructions**

1. Please provide your details in the table below.
2. Please answer ALL the questions as accurately as you can.
3. *There is only one correct answer for every question.*

<i>Your details</i>	
<i>Age</i>	
<i>Gender</i>	
<i>Race</i>	

Select the correct answer in each question by **checking the appropriate box** () on the left. Please also indicate your **confidence** in your answer by checking the appropriate confidence box below.

*Section 1 : Viruses, Bacteria and Protists*

1. A virus is described as:
- (a) a tiny living cell.
- (b) an entity that can reproduce independently.
- (c) an entity that can only reproduce within an appropriate host.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

2. Viruses cause disease in animals.
- (a) True
- (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

3. Bacteria are single celled living organisms that ...
- (a) can live and reproduce independently of a host organism.
- (b) can only live and reproduce within a host animal.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

4. Bacteria are ...
- (a) found in specific environmental habitats.
- (b) almost everywhere.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

## 5. Bacteria...

- (a) cause disease in animals.  
 (b) are not linked to animal disease.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

## 6. Protists are single-celled organisms that ...

- (a) are completely independent and can reproduce outside of a host animal  
 (b) are host dependent and can only reproduce inside a host animal

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

## 7. Protists ...

- (a) have only sexual life cycles  
 (b) have only asexual life cycles  
 (c) may have both asexual and sexual life cycles, depending on the species

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

### Section 2 : HIV/AIDS

## 8. AIDS (Acquired Immunodeficiency Syndrome) ...

- (a) is caused by HIV (human immunodeficiency virus).  
 (b) may be caused by HIV, but HIV and AIDS are not necessarily linked.  
 (c) is a disease caused by unsanitary living conditions and poverty.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

## 9. HIV is passed from one person to another through ...

- (a) transfer of bodily fluids ( e.g. blood, semen, vaginal fluid)  
 (b) kissing  
 (c) casual contact

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

10. What is the most prevalent form of HIV transmission in Africa?

- (a) Mother to baby transmission.  
 (b) Heterosexual (two sexes) sex.  
 (c) Homosexual (same sex) sex.  
 (d) Blood transfusions.  
 (e) Needle sharing amongst individuals.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

11. Wearing a condom during sex ...

- (a) does not completely eliminate your risk of contracting HIV from, or giving HIV to, your partner  
 (b) eliminates any risk of passing the HI virus

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

12. Having unprotected sex on a frequent basis with different partners increases your risk of contracting HIV/AIDS.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

13. People with other sexually transmitted diseases are at a higher risk of contracting HIV/AIDS.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

14. The AIDS test ...

- (a) is completely reliable and accurate.  
 (b) identifies the HI virus in blood.  
 (c) identifies antibodies to the HI virus in blood.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

15. The antibodies against HIV can be present in healthy individuals, but at levels lower than those detected by the HIV/AIDS test.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

16. Which of the following statements is correct?

- (a) People living with HIV show no signs of carrying the disease but only later develop symptoms associated with full blown AIDS.  
 (b) People living with HIV show only minor symptoms after an initial “window period” but later develop more pronounced symptoms associated with full-blown AIDS.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

17. Which one of the following do **not** represent typical symptoms of HIV infection?

- (a) Swollen lymph glands  
 (b) Diarrhoea  
 (c) Yeast infections of the mucous membranes  
 (d) Cold sores

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

### Section 3 : Cancer

18. Cancerous cells lose their ability to divide in a normal fashion becoming out of control and replicating at a rate far greater than normal.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

19. Tumour cells can lead to widespread destruction of normal tissue.

(a) True

(b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

20. Genetic mutations can cause cells to lose control of replication.

(a) True

(b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

21. Cancerous cells live longer.

(a) True

(b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

22. Which one of the following does **not** cause cancer?

(a) A bacterium.

(b) A virus.

(c) Genetic and chromosomal alterations in the cell.

(d) Exposure to chemical carcinogens.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

23. Which one of the following statements is true?

(a) Cancer is infectious and can be transmitted from one individual to another through contact.

(b) Cancer can be inherited from a parent.

(c) A greater risk of developing cancer (genetic predisposition) is inheritable.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

**Section 4 : Malaria**

24. Which of the following agents **causes** malaria in humans?

- (a) A bacterium.  
 (b) A virus.  
 (c) A protozoan parasite (a Protist).  
 (d) An *Anopheles* mosquito.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

25. Malaria can be transferred in saliva.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

26. There are different types of malaria, some more dangerous than others, depending on which species of malaria-causing organism has infected the host.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

27. Which one of the following statements is **false**?

- (a) Wearing long-sleeved shirts and sleeping under mosquito nets in malarious areas reduces the risk of contracting malaria.  
 (b) Use of insect repellents reduces the risk of contracting malaria  
 (c) Anti-malarial drugs are 100% effective against all types of malaria, provided they are taken correctly prior to, during and after exposure to malaria  
 (d) Some malaria-causing organisms have been shown to develop a resistance to some anti-malarial drugs

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

### Section 5 : Tuberculosis

28. Which one of the following organisms causes tuberculosis?

- (a) A virus.  
 (b) A protozoan parasite (Protist).  
 (c) A bacterium.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

29. Tuberculosis is contagious.

- (a) True  
 (b) False

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

30. Tuberculosis is transmitted between people by ...

- (a) the involvement of a second host being part of the tuberculosis-causing agent's life cycle.  
 (b) making the host person sick, enabling the spread of the disease through close contact between the infected person and a healthy person.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

31. Choose the correct statement:

- (a) Tuberculosis is a diseases that indiscriminately targets all income groups in this country and affects all people equally.  
 (b) Tuberculosis is a disease where those that live in poverty are more susceptible to infection because tuberculosis is more easily spread in over-populated, badly ventilated living quarters.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

32. Which of the following reduces the spread of tuberculosis?

- (a) Working in a small, confined stressful office environment.  
 (b) Being outdoors most of the time.

Confidence			
Not confident (1)	Slightly confident (2)	Fairly confident (3)	Very confident (4)

**End of Questionnaire.** – Thank you for your time

## APPENDIX B

### *Storyline and Character Questionnaire*

*Virtual Learning Space Project*

University of Natal

Durban

#### *Introduction*

The Virtual Learning Space (VLS) project is a group currently involved in the design of a 3-D virtual world computer adventure game that teaches students about, amongst other things, prominent diseases in Africa. To develop an educational game that will be interesting and exciting to play, it is necessary to first find out what you think about the storyline we have designed for this game.

It would be greatly appreciated if you could please read the story on this questionnaire and then fill in the answers in the spaces provided. There are no right or wrong answers – we're simply asking you for your opinion.

This questionnaire is completely voluntary and is also completely anonymous. You do not need to provide us with any of your personal details.

For the purpose of knowing who our target student group is, you are asked to provide a few general details about yourself.

Age	
Race	
Sex	

#### **Instructions:**

Please read the story written on the following pages and then answer the questions that follow in the spaces provided.

## Story

Dr. Meisner, after having qualified from a South African University, has moved around the world to various academic institutions around Europe and the Americas, working in the AIDS field. On returning to South Africa Meisner has established a company (called Syntech) that manufactures anti-retroviral drugs. Frustrated by the long process of FDA testing, Meisner has taken to illegal anti-retroviral testing on humans.

While doing research on institutions where an internship could be done, Carua (a medical intern) hears about Meisner's pioneering work. Carua meets Meisner and manages to "convince" the doctor to establish a laboratory near Carua's native village in the North African country, Quania. Carua's motive is to return to Quania and help the native people. The outbreak of ailments such as TB and dysentery amongst the Quanian people, heightens Carua's hope that Meisner, with a significant capital contribution and medicines, will be able to better the lives of the people.

Meisner, on the other hand, sees the opportunity to cure their current diseases, win their trust, and then experiment with the anti-retrovirals on the village people, doing all of this whilst keeping Carua in the dark as to these motives. Fortunately, HIV hasn't been a problem for the people of Quania as they have been largely isolated from the world. Meisner realises that the healthy people will have to be injected with HIV-positive serum before the anti-retrovirals can be tested on them.

Within the village, Carua's cousin, the village leader, is quickly cured of TB when afforded medical treatment by the doctor. This, along with the influence of the intern, builds the confidence of the villagers in Meisner. This opens the door for Meisner to begin the human testing regime under the auspices of "immunization against further disease". Predictably, with time the villagers begin to get sick again. This time, though, the anti-retrovirals do not work as anticipated, and people start to die in numbers. This introduces much tension in the villagers, polarized by the village leader (who has pledged allegiance to Meisner and Carua) on the one hand, and the wary, all-seeing and powerful sangoma on the other hand.

The sangoma is the voice of dissent against Meisner in the village. The Sangoma has the power to see through Meisner's façade and tries to convince the villagers of their folly if they choose to follow the doctor.

With the ever-increasing numbers of dead, and ever present disease, the villagers become confused as to what is right and wrong and start to form two different "factions" - one for ' , and one against.

The game player arrives amongst these tensions. When the gameplayer arrives in the village, they know nothing about what is, or has been, happening. Through various educational puzzles, riddles, interactions with the story characters and visual clues, the gameplayer must piece together what is happening, and what the possible cause of all this disease has been. In so doing, they would threaten the isolated and illegal dealings of Meisner, and as such, they would need to keep a low profile.

The story environment consists of a six main areas:

The first of these is the burning ground where the dead villagers are burned (under Meisner's instruction). Meisner insists this is to curb the further spread of the disease, but it is actually to destroy any evidence of drug testing on these victims. Well placed visual clues in this environment provide clues to the gameplayer about the existence of some kind of drug in the village, the company that supplies these drugs and the death of the villagers.

The second area is the field laboratory (a prefab building) that contains most of the equipment for disease testing, in particular, the testing of blood for HIV and malaria infection. Meisner, however, keeps the results of the HIV testing from Carua and the gameplayer as this would give away the plot. On the walls of the lab are posters showing the structure and infective mechanism of HIV, as well as the life-cycle and infective mechanism of malaria. There is also an ELISA reader, used in testing blood samples for HIV, as well as a powerful microscope to see the infective stage of the malaria life-cycle in the blood of humans.

The third area is adjacent to the laboratory and is the Dr Meisner's office. The walls of this office are lined with Dr. Meisner's certificates and qualifications showing the gameplayer that Meisner is well travelled and very experienced in the AIDS field. On the doctor's desk is a paperweight model showing the structure of a bacterium, as well as a 3-D model of the proposed structure of the HI virus. On the doctor's computer is a copy of an email showing a letter written by Carua to the funders addressing concerns of ill health in the population, and this email has been modified by Meisner, before being sent, to read only positive comments about the project. This serves to heighten suspicion against Meisner in the gameplayer's mind. Inside the doctor's desk drawer is the doctor's personal journal, documenting the death, through cancer, of a person close to Meisner. In addition, there are numerous other articles and newspaper clippings about HIV/AIDS, malaria, TB and cancer research in South Africa which have been inserted into the journal.

The fourth area of interaction is the village. This is where the gameplayer meets the village leader and the sangoma, as well as a few other villagers, and has the opportunity to ask these characters what they think has been happening. This serves to help the gameplayer to start thinking about what is really happening. In the

village huts, the presence of special candles burning continuously hints at the preventative measures that have been taken, under Meisner's direction, by the villagers to reduce the incidence of malaria in the village.

The fifth area of interest is the sick tent. This is where all the people subscribed to Meisner's regime of drug testing are kept, especially when they become too sick to live a normal life. This scene contains a big tent with many beds arranged in a dormitory layout, with each bed housing a sick person suffering either from a rare type of cancer, malaria or tuberculosis. In fact, all of them are suffering from AIDS, but this fact is concealed from the gameplayer and Carua. Because these patients have full-blown AIDS, they are far more prone to opportunistic infections such as malaria and tuberculosis, to which they are usually immune. Furthermore, the presence of the rare form of cancer (Kaposi sarcoma) is characteristically usually only found in AIDS patients. The gameplayer needs to work out what is wrong with the people, and try and ascertain why they are falling ill to diseases against which they are normally immune. The equipment for diagnosing tuberculosis infection is also located inside the sick tent, where it is easily accessible by the player.

The final area of exploration is the doctor's private store-room that only the doctor normally has access to. However, by talking to the villagers and exploring all of the different areas whilst learning about different aspects of the above-mentioned diseases, players acquire different parts of a key that allow them to open the door to the storeroom and access the secret files kept within. When the gameplayer accesses this room, the files detailing the full testing procedure and the deaths of infected villagers are found. By seeing these files, the gameplayer can realise fully what has been happening, why the villagers are dying, and why they are succumbing to diseases against which they are normally immune.

The final resolution of the game is when the player manages to report this to the authorities and the regime of illegal and immoral human testing is exposed.

### **Storyline Questionnaire**

1. What do you think the possible learning objectives of this story could be? Why?

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2. Is the story believable or realistic? Do you think something like this could happen in real life?

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3. What did you like most about the story? Why?

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4. What did you like least about the story? Why?

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5. If you could change any two things in the story, what would you change? And why?

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6. Do you think you'd enjoy playing a game like this? Why?

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7. To motivate players to complete this game, there has to be an ample resolution (payoff/ goal) at the end of the game. Would simply solving the mystery and satisfying your curiosity be enough to motivate you, or could you think of anything you'd prefer to see as resolution to the game?

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8. When the gameplayer discovers the illegal and immoral drug testing on the villagers, they alert the authorities to what Meisner has been doing. What, in your opinion, would be a fitting punishment for Meisner, and why?

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9. (a) Have you ever played a virtual reality adventure game before?

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(b) If so, what was your motivating force to complete the game?

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## Characters

*Dr. Meisner is a ruthless, yet subtle, manipulator, the CEO of a drug company and a very ambitious individual. Dr. Meisner also embodies the evil and unjust practices perpetrated by the greedy element of society.*

10. Based on this information, what do you envisage Dr. Meisner to look like? (in your description, please include factors such as sex, race, age and physical appearance).

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*The medical intern, Carua, is younger and less experienced than Dr. Meisner. Carua is related to the village leader, and is the intermediate between Meisner and the villagers. Carua is passionate about Quania and its people and tends unselfishly to the villagers needs.*

11. Based on this information, what do you envisage Carua to look like, and why? (in your description, please include factors such as sex, race, age and physical appearance).

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*The leader of the village is related to Carua (cousins). The leader has recently been cured, by Meisner, from tuberculosis and is still in the stages of recovery from this disease. The leader is one of the prominent members of the village whose thoughts are greatly respected and whose words are dutifully obeyed.*

12. Based on this information, what do you envisage the leader to look like, and why? (in your description, please include factors such as sex, race, age and physical appearance).

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*The sangoma of the village is a wise person. They have spiritual powers and abilities to see things that nobody else can. They are highly revered, respected and even feared by the villagers because of their mystical powers. The sangoma knows something about Dr Meisner is amiss and helps the gameplayer to solve the mystery.*

13. Based on this information, what do you envisage the sangoma of the village to look like, and why? (in your description, please include factors such as sex, race, age and physical appearance).

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***End of Questionnaire***

Thank you for your time.

## APPENDIX C

### ORIGINAL CHARACTER DEFINITIONS

#### **Dr. Meisner**

A Professor of a South African University. Meisner, a man of mixed race, hails from South Africa but has also had extensive experience overseas at numerous academic institutions. He is a subtle yet ruthless manipulator. He has branched out of academia and has started his own company called Syntech. Under Meisner's guidance, this company manufactures anti-retroviral drugs that are still in the development and testing phase. Meisner has come to this remote village in North Africa (Quania) to test these antiretrovirals on the local inhabitants of the village. He believes that what he is doing is for the good of the world and believes in his own mind that the end will justify the means.

*Physicality* – slick appearance. Look like a refined gypsy. An ace manipulator.

#### **Carua**

A man in his mid-twenties, originally from Quania. He is related to the headman in the village (cousins). He has recently completed his studies and is currently undergoing his internship. He is multilingual and is therefore a good intermediate between Meisner and the villagers. He is respected and liked by the villagers and shows great empathy for his people. He honestly believes what Meisner is doing is for the good of his people.

*Physicality* – A tall black man with good stature. Short hair. Wears a lab coat while working.

#### **Headman**

Aged. The village spokesman who is under the spell of Meisner. He has managed to convince the village that Meisner and Carua are there to help them. He trusts his cousin (the intern) and has, himself, been cured of TB by Meisner. He therefore believes in the power of Meisner's medicine.

*Physicality* - A old frail man whom the village look up to and obey. TB has taken its toll on his appearance, leaving him looking weak and frail.

**Sangoma**

The local spiritual guide. A powerful elderly woman resident in the village who has spiritual powers. She is established and also highly respected within the community.

*Physicality* – An elderly woman. During the day she is dressed as all the other villagers. During rituals, she gets dressed in her traditional ritual regalia. Very distinguishable by her outfit and the presence of beads (the combinations of these beads tells a story about her).

## APPENDIX D

### PRE-GAMEPLAY AND POST-GAMEPLAY QUESTIONNAIRES

#### *Introduction*

The Virtual Learning Spaces (VLS) research group has been involved with the design of a 3-D virtual world computer adventure game that teaches students about various topics. One of the levels that has been designed covers topics such as HIV/AIDS, tuberculosis, malaria and cancer, all prominent diseases in Africa. This study aims to determine whether the more engaging characteristics of adventure gaming could provide an interesting way in which to facilitate deeper learning and more comprehensive understanding of the topics presented.

This development is a formative process and feedback while making the game is essential. For this reason the questionnaires and interview will try and establish three main things: Firstly if the portal helped learners gain a better understanding of the concepts presented, secondly how effective and intuitive the game interface is and finally whether these types of learning environments are better suited to certain learning styles.

This questionnaire has a mix of open-ended questions and prescribed multiple choice questions and is **not** a test. The questionnaire is also completely anonymous, but for analysis purposes I ask that you simply provide your demographic information at the bottom of this page.

The questionnaire comprises of 26 brief questions, each of which has a rating associated with it. Please rate your confidences from 1 (low) to 4 (high) on these scales simply by circling the applicable value.

Thank you for your time.

Rob Seagram  
VLS Project  
University of Natal  
Durban.

#### **Instructions**

Please provide your demographic details in the table below.  
Please answer the questions to the best of your ability  
Please rate your confidence in the answer you provide.

<b>Your details</b>	
Age	
Gender	
Race	

### Section 1 : Viruses and Bacteria

1. Briefly explain what is meant to you by the biological term 'virus' (include a description of size and where they occur)

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*Please rate your confidence in your description*

1	2	3	4
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2. Would you describe a virus as living or non-living?

- a. Living  
 b. Non-living

Why?

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*Please rate your confidence in your answer*

1	2	3	4
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3. Briefly explain what is meant to you by the term 'bacteria' (include a description of size and where they occur)

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*Please rate your confidence in your description*

1	2	3	4
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4. Bacteria ...

- a. can live and reproduce independently of a host organism.  
 b. can only live and reproduce within a host animal.

*Confidence*

1	2	3	4
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5. Bacteria...
- a. cause disease in animals.
  - b. are not linked to animal disease.

<i>Confidence</i>			
1	2	3	4

## Section 2 : HIV/AIDS

6. AIDS (Acquired Immunodeficiency Syndrome) ...
- a. is caused by HIV (human immunodeficiency virus).
  - b. may be caused by HIV, but HIV and AIDS are not necessarily linked.
  - c. is a disease caused by unsanitary living conditions and poverty.

<i>Confidence</i>			
1	2	3	4

7. HIV is passed from one person to another through ...
- a. transfer of bodily fluids ( e.g. blood, semen, vaginal fluid)
  - b. kissing
  - c. casual contact

<i>Confidence</i>			
1	2	3	4

8. What is the most prevalent form of HIV transmission in Africa?
- a. Mother to baby transmission.
  - b. Heterosexual (two sexes) sex.
  - c. Homosexual (same sex) sex.
  - d. Blood transfusions.
  - e. Needle sharing amongst individuals.

<i>Confidence</i>			
1	2	3	4

9. Wearing a condom during sexual intercourse...
- a. does not completely eliminate your risk of contracting HIV from, or giving HIV to, your partner
  - b. eliminates any risk of passing the HI virus

<i>Confidence</i>			
1	2	3	4

10. Having unprotected sex on a frequent basis with different partners increases your risk of contracting HIV/AIDS.
- a. True
  - b. False

<i>Confidence</i>			
1	2	3	4

11. People with other sexually transmitted diseases are at a higher risk of contracting HIV/AIDS.
- a. True
  - b. False

<i>Confidence</i>			
1	2	3	4

12. The most widely accessible AIDS test (ELISA test) ...
- a. identifies HIV in the blood.
  - b. identifies antibodies to HIV in the blood.

<i>Confidence</i>			
1	2	3	4

13. The antibodies against HIV can also be present at lower levels in individuals without HIV infection.
- a. True
  - b. False

<i>Confidence</i>			
1	2	3	4

14. What do we mean when we talk about the HIV window period? How would you describe it to someone who'd never heard about it?

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<i>Please rate your confidence in your description</i>			
1	2	3	4

15. If someone asked you to briefly explain what happens when a person becomes infected with HIV/AIDS, what would you say? Please try and include descriptions of the lifecycle and disease progression in your answer.

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<i>Please rate your confidence in your description</i>			
1	2	3	4

16. Briefly explain why people who have AIDS never die from AIDS, but rather from some other disease? Why does this happen?

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<i>Please rate your confidence in your description</i>			
1	2	3	4

**Section 3 : Cancer**

17. If you had to very briefly describe the mechanism of cancer to someone who knew nothing about it, what important points would you put across to them?

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<i>Please rate your confidence in your description</i>			
1	2	3	4

18. Briefly describe what is meant by a 'tumour'.

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<i>Please rate your confidence in your description</i>			
1	2	3	4

19. Genetic mutations can cause cells to lose control of the rate at which they grow and divide.

- a. True  
 b. False

<i>Confidence</i>			
1	2	3	4

20. Cancerous cells live longer.

- a. True  
 b. False

<i>Confidence</i>			
1	2	3	4

21. Which one of the following does **not** cause cancer?

- a. A bacterium.  
 b. A virus.  
 c. Genetic and chromosomal alterations in the cell.  
 d. Exposure to chemical carcinogens.

<i>Confidence</i>			
1	2	3	4

22. Which one of the following statements is true?
- a. Cancer is infectious and can be transmitted from one individual to another through contact.
  - b. Cancer can be inherited from a parent.
  - c. A greater risk of developing cancer (genetic predisposition) is inheritable.

<i>Confidence</i>			
1	2	3	4

**Section 4 : Tuberculosis**

23. Which one of the following organisms causes tuberculosis?
- a. A virus.
  - b. A protozoan parasite.
  - c. A bacterium.

<i>Confidence</i>			
1	2	3	4

24. What are some of the symptoms of a person infected with tuberculosis?

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<i>Confidence</i>			
1	2	3	4

25. Briefly explain how tuberculosis is spread from one person to another.

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<i>Confidence</i>			
1	2	3	4

26. Under what conditions do you think tuberculosis would be most likely to spread and how could this spread be avoided?

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<i>Confidence</i>			
1	2	3	4

## **APPENDIX E**

### **EXPERT PORTFOLIO**

#### **Prof. Photini Kiepiela**

Professor Kiepiela is one of the foremost HIV/AIDS researchers in South Africa. Her research focuses mainly on women with HIV in community settings. She is world-renowned for her work into immune-system genes that appear to play a key role in the body's defence against HIV. She is currently involved with HIV research at the Medical School, University of KwaZulu-Natal, South Africa.

#### **Dr. Stephanie Thomas**

Dr. Thomas is the current Programme Director for the Adherence Support Programme run by the KwaZulu-Natal Department of Health. Dr. Thomas has done extensive research into HIV/AIDS but her main point of contact is now with healthcare workers whom she oversees and co-ordinates. She is the author of a number of HIV/AIDS related books, particularly addressed at health care workers. Dr. Thomas is also affiliated with the University of KwaZulu-Natal.

#### **Ms. Michelle Govender**

Ms. Govender is a bioethics pre-doctoral fellow at the Centre for the AIDS Programme of Research in South Africa (CAPRISA). Her focus is mainly on HIV and ethical issues surrounding the implementation of research programmes for HIV research. Ms. Govender has input into the ethics portion of CAPRISA's studies, particularly the review of informed consent documents, drafting ethical frameworks and provides input into the drafting of multidrug resistance guidelines