Chapter 5

Evaluation of the *EduRom* multimedia software package

This chapter provides a detailed report on one of the factors affecting teachers’ use of ICT for teaching and learning – the influence of software quality – briefly reported on in the previous chapter. The chapter reports on the evaluation (background, conceptual framework and findings) of a multimedia software package purchased by the case study school to serve as support material for teachers within the context of a new curriculum. Any software considered for use as support material must be carefully evaluated to assess, based on our current ideas of what constitutes good teaching and learning, whether it allows for effective instruction and whether its design features (interface design, pedagogical design, multimedia design, and the extent to which the software meets curriculum requirements) are likely to enhance learning.

5.1 RATIONALE BEHIND THE SOFTWARE EVALUATION

A lack of appropriate and timely evaluation of software is believed to be a major factor responsible for the lack of success in using technology to improve learning (Reeves & Hedberg, 2003). The purpose of this part of the study was to assess whether a multimedia software package available at the case study school could support teachers implement the constructivist practices required by the new South African curriculum. I evaluated the instructional, interface and pedagogical design of the package to see whether the software package met the claims made the designers. These included that the software “provides the answer to the latest curriculum”, “provides interactive educational software”, offers “continuous evaluation” and “cover(s) the majority of the new curriculum, based on OBE and e-learning principles”. The claims made by the software company sounded like a feasible mechanism for taking advantage of the benefits offered by integrating ICT into science teaching, while simultaneously helping teachers to address new content, and apply the required principles of the new curriculum in their classrooms.

5.2 DEFINING RELEVANT TERMS

Before discussing the model and theories on which the proposed framework is based, a brief discussion of multimedia software is necessary to allow the reader to understand some of the terms used later in the chapter and to substantiate the need for evaluating multimedia resources.

The term ‘multimedia’ is used to refer to any software or interactive application that integrates some or all of the following components: text, graphical images, animation, audio and video (Rebetez, Bétrancourt, Sangin, & Dillenbourg, 2010; Reeves & Hedberg, 2003; Rieber, 1994). Reed describes multimedia simply as “combining words and pictures” (Reed, 2006, p. 87). The words and pictures Reed refers to can be used in different formats e.g. words can be written or spoken while pictures may be static or animated. Reed further points out that the different formats in which words and pictures can be used allow for different combinations. In an educational context different combinations of words and pictures can have different effects on learning, as will be explored later in this chapter.
Computer-based multimedia software can act as interactive systems because of their unique ability (as opposed to other types of media like videos and films) to initiate an interaction with learners (Domagk, Schwartz, & Plass, 2010; Evans & Gibbons, 2007). Where multimedia packages make use of interactivity they are referred to as ‘interactive multimedia’ (Reeves & Harmon, 1994). Some researchers regard interactivity as essential to multimedia. For example, Feifer and Tazbaz claim that “without interactivity, a multimedia title can just as easily be delivered on a video tape as by the computer” (Feifer & Tazbaz, 1997, p. 52).

5.3 WHY EDUCATIONAL MULTIMEDIA SHOULD BE EVALUATED

Evaluation, in its purest sense, is defined as … a judgement of merit or worth against a predefined set of standards or expectations. The evaluation process is used to assign a value to the ‘object’ being evaluated so that its worth or intrinsic value can be conveyed to others. (Thornton & Phillips, 1997, p. 127)

Thornton and Phillips point out that ‘evaluation’ has a different connotation when applied to the use of multimedia resources for instructional purposes. The emphasis shifts from assigning some intrinsic value to the multimedia resource being evaluated to assessing its effectiveness in enhancing learning (Thornton & Phillips, 1997). Not only does the emphasis of evaluation of multimedia resources differ from the definition of evaluation provided by Thornton and Phillips, the purpose of evaluation should also be different when applied to multimedia resources in an educational setting. The purpose of evaluation should not necessarily be just to convey the value of a multimedia resource to others, but to assess the usability of the resource within a particular context (Reeves & Harmon, 1994). Combining the need for evaluation of instructional software with the usability of the resource within a particular educational setting suggests that, as claimed by Reeves and Hedberg (2003), multimedia software should be evaluated within the context of its use and the characteristics of its users. A comprehensive framework for evaluating multimedia software should make provision for factors both within and extraneous to the context of use of the software.

5.4 THEORETICAL FRAMEWORKS AND SOFTWARE EVALUATION

The importance of conducting educational research within a theoretical framework was discussed at the beginning of in Chapter 2 (see Section 2.1). However, as some authors have pointed out, “developing theory for educational technology is difficult because it requires a detailed understanding of complex relationships that are contextually bound” (Mishra & Koehler, 2006, p. 1018). Many previous evaluation frameworks relating to educational technology have focused on particular aspects of ICT use in education. Because of the focus on certain aspects of ICT, no single, unifying framework could be found within which to situate the software evaluation aspect of this study.

I have chosen to deal with the lack of a single framework for software evaluation by starting at one end of the continuum of frameworks described by Abd-El-Khalick and Akerson (2006). These researchers believe that at one end of the continuum of frameworks a listing of different theories from different disciplines may provide a structural framework for a research study. I analysed several existing theories dealing with software evaluation to elicit a set of criteria against which the educational software in this study could be comprehensively evaluated. The theories used include the
perspectives interactions paradigm (which focuses on the context of use of educational software and the interactions between the designer, teacher and learner), dual coding theory and the working memory model (which deal with the cognitive aspects of learning) and cognitive load theory and multimedia learning theory (which deal with how learning occurs with multimedia software). I combined pertinent aspects of these theories into a model for software evaluation in a way that acknowledges that there are two sets of factors which affect the usefulness of software, factors that depend on the context of use and factors that are independent of the context of use. The model for software evaluation I propose moves to the other side of the continuum of frameworks suggested by Abd-El-Khalick and Akerson. The software evaluation aspect of this study will be situated within this context-based model.

### 5.4.1 Perspectives interactions paradigm

Squires and McDougall (1994), the developers of what these authors call ‘the perspectives interactions paradigm’, aimed to shift the focus of software evaluation away from the technical aspects of software to focus on how the software is used to enhance teaching and learning. To achieve this aim the perspectives interactions paradigm approaches software evaluation from the perspectives of the three main role players in software use, designers, teachers and learners. The three role players are shown in Figure 29. The ‘paradigm’ is based on the concept of ‘paired perspectives’, which refers to the direct and/or indirect interactions between pairs of role players, resulting in three pairs of mutual interactions, as explained after the figure.

![Figure 29. The relationships which form the basis of the perspectives interaction paradigm (Squires & McDougall, 1994)](image)

- **The interactions between designer and learner.** The influence of the designer’s perspective on the learner is represented in Figure 29 as a solid arrow. Despite the designer’s absence from the classroom, Squires and McDougall believe that the designer’s perspective, as implicit in the design of the software, has a direct influence on the learner’s experience of the software.

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5 The word ‘paradigm’ is incorrectly used here. As discussed in Chapter 3 (Section 3.1.2, page 66) a paradigm reflects a belief system underpinned by a particular ontology which influences a researcher’s epistemology and methodology. It would be more appropriate to refer to the perspectives interactions model, as it focuses on modelling the relationships between role players in a given situation.
The designer would typically have considered how the learner would “relate to and use the software” (Squires & McDougall, 1994, p. 68). The effect of end-users (learners) on the designer is represented by a dotted arrow in Figure 29 as the designer usually has no direct knowledge of specific learners, using only perceived characteristics of typical users to influence decisions about how to design the software. Squires and McDougall explain that direct feedback from specific targeted users (which could then be represented by a solid arrow) would occur only in certain circumstances, such as during a formative evaluation.

- **The interactions between designer and teacher.** According to Squires and McDougall, the nature of the relationships between the designer and teacher perspectives mirrors those of the designer and learner, except that, in the case of well-designed software, the designer might have been more concerned with curriculum issues and teaching approaches than with technical issues relating to the usability of the software.

- **The interactions between teacher and learner.** Unlike the other two paired perspectives, the interaction between the teacher and learner is a direct bi-directional one (represented by the two solid arrows in Figure 29), since it represents the direct interaction between two active parties in teaching-learning situations, the actions of each impacting on the other (Squires & McDougall, 1994).

### Application of the perspectives interaction framework to evaluating instructional software

Squires and McDougall assert that software evaluation “can only have meaning in the context of the classroom situation in which is to be used” (Squires & McDougall, 1994, p. 112). The relevance of the perspectives interactions paradigm to software evaluation is that it emphasises the importance of conducting such evaluation within a context and taking into account the characteristics of the users and the interactions between the users. An approach to software evaluation based on how the software will be used should focus on the paired relationships between learner, teacher and designer, which would emphasise “educational considerations such as classroom interactions, theories of learning processes, and curriculum issues” (Squires & McDougall, 1994, p. 112). Each of the paired relationships shown in Figure 29 raises different issues about software use and how software should be evaluated:

- **Teacher-learner interactions.** Software use in the classroom has implications for the teacher-learner dynamic. Appropriately-designed software has the potential to initiate “off-computer activities such as class discussion [and] small group research projects” (Squires & McDougall, 1994, p. 72). According to Squires and McDougall such social interactions in the classroom can take place through learner-teacher interaction or through interactions between learners. These researchers claim that, especially in the case of learner-learner interactions (e.g. in small group interactions), the use of software that promotes off-computer activities provides opportunities for learners to take more responsibility for their learning, as the teacher may have less direct involvement with learners. According to Bishop (1993, as cited in Squires and McDougall, 1994, p. 81) the use of software “in ways that exploit the learning potential” of teacher-learner and learner-learner interactions can have implications for the role of teachers. Squires and McDougall suggest that teachers may find that they are required to manage and facilitate learning activities promoted by the software rather than assuming the more traditional role of delivering information. Software packages may provide printed or audiovisual material to be
used together with the software in classroom activities. For other packages, the teacher may have to devise activities based on the software. Evaluation of software from the perspective of the teacher-learner interactions could therefore focus on whether software use promotes appropriate off-computer activities or whether teachers will have to structure activities around the software.

- **Designer-learner interactions.** Squires and McDougall (1994) emphasise that the value of educational software lies in its ability to enhance learning. These researchers state that this requires an evaluation of the learning theory underpinning the approach to the software design, whether that learning theory is explicitly stated, e.g. in the software documentation, or whether it is implicit in the design of the software. The software package evaluated in this study claimed to have been designed according to the constructivist principles which underpinned the curriculum changes being introduced in South Africa during the early part of this study. The pedagogical strategies used in the package to promote constructivist learning was one of the aspects evaluated, for which the results for which are reported in Section 5.8.3 on page 184. Where no underpinning learning theory exists (or seems to exist), Squires and McDougall believe that software cannot be expected to have much educational value. The importance of evaluating the learning theory underpinning educational software is to determine "whether the software design is consistent with the approach to learning in the classroom environment that the software is intended to support" (Squires & McDougall, 1994, p. 90).

- **Designer-teacher interactions.** The interaction between the perspectives of designer and the teacher (as the person selecting the software) is embodied in the relationship of the software to the curriculum (Squires & McDougall, 1994). These authors state that

  … the design of the software incorporates a representation of the designer’s perception of the curriculum, so assessment in the context of the designer-teacher interaction becomes a question of the extent to which the designer’s perception of the curriculum matches that of the selector. (Squires & McDougall, 1994, p. 100)

Software evaluation would involve interpreting how well the designer has met curriculum requirements. Curriculum requirements are typically defined in terms of educational content and process (Squires & McDougall, 1994). Educational ‘content’ refers to the facts, concepts and principles included in the curriculum (the equivalent of ‘substantive content’ as explained by Schwab [1978]), while ‘process’ can be interpreted as the non-content based principles unpinning the curriculum (such as learner-centred teaching and activity-based learning in the case of the South African curriculum which had just been introduced). Squires and McDougall point out that some packages may clearly state which curriculum they are aligned to, but even where this is not the case the content included often provides evidence of alignment to a particular curriculum. According to these researchers it is easier to identify which curriculum a package is aligned to because of the subject-specific content. This had great relevance in my study, where the software package being evaluated had not been specifically designed for the new South African Life Sciences curriculum introduced in 2006 (see pages 99-105 in Chapter 4).
Shortcomings of the perspectives interactions paradigm

As stated previously, Squires and McDougall (1994) aimed, when developing the paired perspectives paradigm, to shift the focus away from evaluations based solely on the technical aspects of software. However, the technical aspects cannot be entirely neglected because of the impact of the technical design of software packages on learning. Nevertheless, the perspectives interactions paradigm provides useful insights for those designing evaluations in that it focuses on the importance of the context of the educational situation in which software is to be used.

5.4.2 Theories of cognitive architectures for multimedia learning

The theories discussed in this section provide insights into how learning takes place cognitively and suggest design principles that should be considered when evaluating the potential of a software package to enhance learning. These theories were used to develop the multimedia design principles against which the software package was evaluated in this study (see Section 5.5.3 on page 141).

Theories of the architecture of the human cognitive system

The basic premise for understanding the human cognitive system is that it consists of working memory and long-term memory (Kirschner, 2002; Sweller, 1994). For learning to take place information has to be processed in working memory before being stored permanently in long-term memory as information that is not currently in use, but which can be drawn on to assist with understanding new information (Kirschner, 2002). The following two theories are relevant to understanding basic human cognitive architecture and how learning with multimedia software takes place. Such an understanding of the cognitive basis of learning with multimedia will suggest criteria against which the potential of multimedia packages to enhance learning can be evaluated.

- **Dual coding theory (Paivio, 1986).** The original theory was proposed by Paivio in 1971. The version described here is the modified version of the theory outlined by Paivio in 1986, of which a schematic representation is shown in Figure 30.

![Figure 30. A schematic representation of dual coding theory (Paivio, 1986)](image-url)
Dual coding theory assumes that cognitive or internal representations of the real world originate in sensory experiences. The theory further assumes that structures and processes used to represent the real world internally retain the modalities of the original stimuli. Dual coding theory proposes the existence of two modality-specific sub-systems in the brain that are used to represent the external world internally. The first sub-system is a verbal sub-system for processing verbal stimuli consisting of written words, auditory words and/or writing patterns. These stimuli are represented in the verbal sub-system as representational units which Paivio calls 'logogens'. The second, non-verbal sub-system, processes non-verbal information like visual objects and represents them internally as representative units called 'imagens'. The logogens and imagens referred to by Paivio are hypothetical units used to represent the external world internally. The verbal and non-verbal sub-systems are structurally and functionally separate in the brain and are able to operate either independently or simultaneously. According to Paivio, however, "the preferred metaphor in dual coding" (Paivio, 1986, p. 62) is that activity in one system can initiate activity in the other, leading to the dual processing of incoming stimuli.

Three types of processing take place within and between the two sub-systems (see Figure 30):

- **Representational processing.** Incoming verbal or non-verbal stimuli trigger verbal representations and non-verbal representations in the respective sub-systems, e.g. seeing an object (like a table) will trigger a visual representation of the object (which at this stage is unnamed) in the non-verbal subsystem.

- **Associative processing.** Connections are made between information within either the visual or verbal sub-system, e.g. an attempt will be made to organise the object (in this case, the table) into some scheme of images within the non-verbal system (like a table set for dinner in a dining room).

- **Referential processing.** Activity in each sub-system can activate the other sub-system through referential connections and lead to the naming of objects or conjuring up an image to match a word, e.g. the image of the object triggers activity in the verbal sub-system to find an appropriate name (like dining table) for the object.

As Reed (2006, p.88) points out, dual coding theory does not make provision for the integration of the verbal and visual information because "the two codes are only better than a single code if they are least partially independent". However, the concept of separate, modality-specific but inter-connected cognitive sub-systems for processing incoming information laid the groundwork for later theories dealing with multimedia learning.

- **Theory of working memory (Baddeley, 1986, 1992).** Since the work of Miller (1956), it has been accepted that the capacity of working memory is limited. Miller provided empirical evidence that working memory can hold only about seven (± 2) elements of information at a particular time. Baddeley, in his theory of working memory, proposed a model which, similar to dual coding theory, used a verbal and a visual code but did not make provision for integration of
the dual modalities. Importantly for multimedia learning, however, this theory emphasised the
difference in capacity between working memory and long-term memory.

Based on the work of Miller (1956) and Baddeley (1992), long-term memory is now seen as an
unlimited repository of information that can be stored indefinitely (Sweller, 1994), but working
memory is restricted to holding about seven (± 2) elements of information (Miller, 1956;
Baddeley, 1992). When new information needs to be processed (organised, compared, contrasted), the capacity of working memory is reduced to two or three items of information
(Kirschner, 2002). It is therefore the capacity of working memory that restricts learning. The
idea of working memory being limited is important for both of the cognitive theories of
multimedia learning discussed below.

Theories of how multimedia learning happens, based on cognitive architecture

The two theories of cognitive architectures for multimedia learning described below focus on “different aspects of multimedia learning” (Reed, 2006, p. 87). Reed describes these two “instructional” theories as having been developed to “formulate principles for effective instruction” (Reed, 2006, p. 92).

• Cognitive load theory (Sweller, 1994). Cognitive load theory is concerned with the
implications of a limited-capacity working memory for instruction. The theory is based on the
limited capacity of working memory as described in the theory of working memory (Baddeley,
1992). According to Sweller, the limited capacity of working memory means that it can only
handle a limited number of elements of information before it becomes overloaded. When
working memory becomes overloaded information will not be processed efficiently from working
memory to long-term memory, thus hindering or preventing learning. The strategies used in the
EduRom package to reduce cognitive load are reported in Section 5.8.5, starting on page 208).

According to cognitive load theory there are two ways of overcoming the limited capacity of
working memory. The first way software users can use is by automating some cognitive
processes. Sweller suggests that cognitive processing can either be controlled (requiring
deliberate thought) or it can take place automatically (without conscious effort). Automatic
processing typically involves material or information that users have mastered and therefore do
not have to consciously process. Because the automation of cognitive processes does not
require conscious effort, automatic processing requires less working memory capacity than
controlled processing, thus freeing up cognitive resources for other activities. The second way
of overcoming the limited capacity of working memory involves learners forming schemas which
incorporate smaller units of knowledge. Long-term memory can handle a much larger number
of elements than working memory by using cognitive constructs known as schemas or
schemata. Sweller points out that the concept of schemas as cognitive constructs that contain
multiple elements of information, which individuals organise according to how the individual will
use the information when processing incoming information, was first proposed by Chi, Glaser,
and Rees (1982). In Sweller’s theory, individuals subconsciously compare incoming information
with their existing knowledge (in the form of the schemas they already have present in long-
term memory) and attempt to incorporate the incoming information into their existing knowledge
(hence the importance of prior knowledge in learning). Information is deemed to have been
learned when new information has been incorporated into a schema and enters long-term
memory for storage. Schema formation provides a way of overcoming the limited capacity of working memory by “chunking” a number of individual elements into a cognitive construct regarded as a single element in working memory (Sweller, 1994, p. 299).

As Sweller points out, cognitive load theory provides a framework for investigating how the structure or presentation format of information affects, or is likely to affect, cognitive processing of that information. The theory identifies three categories of cognitive load, where cognitive load can be understood as the number of elements of information that have to be processed in working memory before information can pass into long-term memory for learning to take place. The software package evaluated in this study claimed to have been designed according to “e-learning principles”, thus one of the aspects focused on was the extent to which the software design would minimise cognitive load. The three categories of cognitive load are:

- **Intrinsic load.** According to Paas, Tuovinen, Tabbers, and van Gerven (2003), the intrinsic load imposed on learners by learning material depends on the degree of interactivity of the elements to be learnt. These authors explain that low-element interactivity material consists of information elements that can be understood individually, while high-element interactivity material consists of information elements that can be understood individually, but need to be present in working memory at the same time for processing to occur. High-element interactive material therefore places a greater cognitive demand on learners. Intrinsic load is inherent to the specific material to be learnt and cannot be influenced by the design of the instructional material (Paas et al., 2003). Leppink, Paas, van Gog, van der Vleuten, and van Merriënboer (2014) point out that “the intrinsic cognitive load that is imposed by a learning task or learning materials is much higher for novices than for more advanced students” (Leppink et al., 2014, p. 32).

- **Extraneous load.** Extraneous load refers to the demands placed on working memory by the format used to present information and the sorts of learning activities learners have to carry out (Ayres & Paas, 2007; Brunken, Plass, & Leutner, 2003; Paas et al., 2003). If the extraneous load is too great, it can interfere with learning by taking up space in working memory and interfering with the processing of information and the possible formation of schemas (Paas et al. 2003). An example of a heavy extraneous cognitive load occurs when learners have to search for information referred to in a body of text but which is not readily available or accessible (Paas et al. 2003). Brunken et al. describe this type of cognitive load as a “form of overhead” (Brunken et al., 2003, p. 54) that uses up cognitive resources, but does not contribute directly to learning. Extraneous load is dependent on the design and structure of material to be learnt, which has implications for the design of multimedia instructional material.

- **Germane load.** Kirschner (2002, p. 4) offers a useful way of distinguishing between extraneous and germane cognitive loads with the statement that “conventional instructions tend to impose an extraneous cognitive load on working memory, whereas learning something requires shifting from extraneous to germane cognitive load”. Whilst extraneous load is concerned with understanding instructions, germane load involves knowledge construction, in that schemata are re-organised to incorporate new information. Germane cognitive load thus occurs when working memory capacity is used to organise elements of new information into existing schemata and to automate schemata (Bannert, 2002;
Kirschner, 2002). Leppink et al. (2014) point out a recent shift from the term ‘germane cognitive load’ to ‘germane resources’ to focus on the working memory resources allocated to dealing with intrinsic cognitive load. Similar to extraneous cognitive load, germane cognitive load is influenced by the instructional design of material (Paas et al., 2003).

The three categories of cognitive load are additive, and the total load cannot exceed the capacity of working memory if learning is to take place (Paas et al., 2003). Since extraneous cognitive load and germane cognitive load can be influenced by the instructional design of material, cognitive load theory has contributed to a number of principles of instructional design aimed at enhancing learning with multimedia applications through reducing total cognitive load. These principles have been included as appendices, as will be discussed later in this chapter, and used to develop a set of principles for evaluating the multimedia design of the software package evaluated in this study.

- **Mayer’s multimedia learning theory.** Because this theory (Mayer, 1977; 2001) draws on the other theories of cognitive architecture, it is useful for understanding how human cognitive structure works in relation to multimedia learning. Three assumptions, which are based on the three cognitive theories described previously, underlie Mayer’s cognitive theory of multimedia learning. The concept of the human cognitive system consisting of dual coding systems (an auditory channel for processing auditory information and a visual channel for processing visual information) is drawn from dual coding theory (Paivio, 1986). The idea of working memory having a limited capacity is taken from Miller (1956) and the theory of working memory Baddeley (1986). The final assumption is based on Sweller’s notions of intrinsic and extraneous cognitive load which Mayer has used to propose ways to reduce extraneous cognitive load (Reed, 2006). The multimedia learning theory is summarised in Figure 31.

![Figure 31. Cognitive theory of multimedia learning](Mayer, 2001 [based on the work of Miller, 1956, Paivio, 1986 and Baddeley, 1986], as cited in Reed, 2006)

According to this theory, information from a multimedia presentation is received by the ears and eyes, from whence certain bits of visual and auditory information are selected to enter working memory (Mayer, 1997). Mayer’s theory also holds that within working memory, associative connections are made between information within the visual and verbal channels, but referential connections are also made between information in the two channels.

According to Mayer, the next step in cognitive processing involves learners organising the aspects of the verbal information in the visual channel into a verbally-based internal...
representation or model and the parts of pictures selected into an image-based internal representation or pictorial model. The final step involves learners integrating the verbal mental model and the pictorial mental model with each other, and with any relevant prior knowledge present in learners’ long-term memory. The integrating process takes place in working memory. Sweller (2006) explains that learning is judged to have taken place when the contents of long-term memory have been changed by the addition or re-arranging of information.

Taking into account the limited capacity of working memory, Mayer and others have amassed empirical evidence for a number of multimedia design principles that should be followed so as to maximize the potential of a multimedia application to promote meaningful learning, i.e. learning in which the individual is actively involved in “selecting relevant information, organizing that information into coherent representations, and integrating those representations with existing knowledge” (Moreno & Valdez, 2005, p. 36). The principles gleaned from the literature will be discussed later in this chapter (see Section 5.5.3 on page 141).

Shortcomings of the cognitive theories of multimedia learning

The cognitive theories of multimedia learning provide valuable principles which can be applied in designing multimedia, and which could be used when evaluating educational multimedia software. Cognitive load theory, especially, has come to occupy “an increasingly central role in the education research literature” (de Jong, 2006, p 105). However, an evaluation of multimedia software based on these theories will be focusing primarily on the design of the software and not on the context within which the software is being used and the characteristics of its users.

5.5 CRITERIA FOR A COMPREHENSIVE EVALUATION OF MULTIMEDIA EDUCATIONAL SOFTWARE

An analysis of the theories of how multimedia learning happens (see page 136 onwards), suggests that the following criteria should be considered when evaluating the potential for software to promote meaningful learning: interface design (for technical and usability issues), instructional design for pedagogy (to evaluate the underlying learning theory), and instructional design for interactive multimedia (to evaluate ability to promote meaningful learning).

5.5.1 Interface design

The user interface (screen) provides a means of displaying data to the user so that information can be extracted from the data and assimilated by the user (Reeves & Harmon, 1994; Smith & Mosier, 1986). The interface represents the medium via which users interact with the content of a multimedia system. The following extract highlights the importance of interface design in influencing the overall usability of interactive multimedia and, ultimately, the construction of knowledge by the learner:

While more information, delivered faster, in multiple media is good, it is almost useless without a good interface. While good human-computer interfaces are important in all software areas, they are essential to allowing the user to interact in any meaningful way with a multimedia environment. (Feifer & Tazbaz, 1997, p. 51)

Perry and Schnaid (2012) highlight the following aspects of designing educational software interfaces:
To say that educational software is focused on teaching and learning is more than to merely state its purpose. It also conveys the commitment to translate the theoretical interpretation of these processes into an instructional design and into a user interface. This is not an easy goal to meet, as there are no direct and objective means to translate any theoretical interpretation into software features. (Perry & Schnaid, 2012, p. 723)

The literature suggests that interface design is important because a well-designed screen will initially draw learner's attention to the data being displayed and could contribute to learners assimilating information without confusion and fatigue (Lee & Boling, 1999; Oud, 2009). Screen design may also affect the motivation of the user to continue to use the software (Lee & Boling, 1999; Stemler, 1997). Finally, the organisation of the data on the screen influences reading speed and comprehension on the part of the learner (Hannafin & Hooper, 1989). In terms of cognitive load theory, instructional multimedia software with a poorly designed interface will increase the extraneous load on users, thereby impeding the processing of information in working memory, which could, ultimately, contribute to cognitive overload.

When evaluating screen design two aspects have to be considered. The first is the graphical design or look of the interface, which includes the use of media elements used to communicate data (text, graphics, animation, and audio), and the display elements (layout, colour, labels, and prompts). The second aspect “involves navigation and the user's path through the product” (Heyden, 2004, p. 96). For the purposes of this study, six categories of screen design elements have been identified from the literature and a series of guidelines developed by which interface design can be evaluated (see Appendix P). The sources used to compile the guidelines in Appendix P are a combination of research reports (e.g. Austin, 2009; Pastoor, 1990), literature reviews of principles for screen design (e.g. Brockmann, 1991; Isaacs, 1987; Reynolds, 1979; Stemler, 1997), and summaries of design principles (e.g. Feifer & Tazbaz, 1997; Marcus, 1992; Oliver & Herrington, 1995; Oud, 2009).

5.5.2 Instructional design for effective pedagogy

As described earlier, Squires and McDougall (1994, p. 112) believe that an approach to software evaluation based on how the software is used should focus on the relationships between learner, teacher and designer, and should emphasise “educational considerations such as classroom interactions, theories of learning processes, and curriculum issues”. While the classroom interactions and curriculum issues would be specific to the context in which the software is being used, it is possible to evaluate the instructional design of software for appropriate pedagogy, independent of the context. Such an evaluation would focus on the underlying design components and strategies that have been included in the software to facilitate effective learning.

A review of the literature suggests that many researchers have tried to condense their ideas of the most important features which constitute ‘good teaching practice’ into finite lists, such as Sorcinelli’s research findings on the Seven Principles for Good Practice in Undergraduate Education proposed by Chickering and Gamson in 1987 (Sorcinelli, 1991), Ramsden’s five criteria for effective teaching and learning (Ramsden, 2003, first published in 1992), or Angelo’s “teacher’s dozen” - fourteen general, research-based principles for improving higher learning in undergraduate classrooms (Angelo, 1993). I developed a framework of learning principles based on the literature, against which I could evaluate the instructional design of the software package used in this study, which is presented in Appendix Q. Many of the learning principles described in the appendix are based on constructivist principles of
learning, according to which learning involves learners actively constructing their own knowledge based on their prior knowledge and the new information to be learnt.

5.5.3 Instructional design for interactive multimedia software

The work of Sweller, Mayer and others has led to a theoretical framework of principles for multimedia learning. These principles can act as guidelines for designers as to what technical features they should include in interactive multimedia educational packages to enhance learning. The principles are summarised as basic principles (see Appendix R) and advanced principles (see Appendix S) for designing instructional multimedia software packages, following the classification of Mayer in his 2005 book. The basic principles involve fundamental issues relating to multimedia design, such as how to best combine words and pictures to enhance learning. The advanced principles promote deeper learning using metacognition. Two multimedia methods which are popular among instructional designers, i.e. animation and interactivity, warrant further discussion.

Animation

The concept of animation is included in Appendix R as an interface design element and in Appendix S as a basic principle to enhance multimedia learning. However, the trend for educational multimedia to make use of animation (as mentioned by Betrancourt, 2005; Lowe, 2003; Ploetzner & Lowe, 2012; and Rasch & Schnottz, 2009) justifies further discussion of this multimedia feature. Some researchers claim that animation, when designed and used according to the principles of multimedia learning theory, could contribute to deeper understanding on the part of the learner (Mayer & Moreno, 2002). The first benefit of animations is that, being graphical, they allow information to be presented in an additional form to text, which allows the processing of two codes (pictorial and verbal) rather than one (see dual coding theory discussed on page 134). Using both channels helps to overcome the limited capacity of each channel, and aids the retention and transfer of knowledge (Fletcher & Tobias, 2005). The second benefit is that animations are useful for depicting changes in process over time (Betrancourt, 2005; Rasch & Schnottz, 2009; Tversky, Bauer-Morrison, & Betrancourt, 2002). Some researchers claim that the dynamic nature of animations makes them highly suitable for representing dynamic content to learners (Ploetzner & Lowe, 2012; Rasch & Schnottz, 2009; Rebetez et al., 2010; Scheiter & Gerjets, 2010; Tversky et al., 2002).

However, a review of the literature (see Kriz & Hegarty, 2007; Ploetzner & Lowe, 2012; Rebetez et al., 2010) produces what Scheiter and Gerjets (2010, p. 436) refer to as “an ambiguous picture” concerning the use of animation to promote learning. Some research suggests a positive effect of animations on learning. After reviewing available research on the topic, Betrancourt concluded that “animation has tremendous potential to improve understanding of dynamic information” (Betrancourt, 2005, p. 295). Höfler and Leutner reached a similar conclusion after conducting a meta-analysis in which they reanalyzed 26 studies on the effects of animation. The meta-analysis produced an effect size of $d = 0.4$, which suggests that animations have a positive impact on learning. Researchers (e.g. Mayer and his co-worker Moreno) have also amassed evidence that animation, when used according to specific design principles (see Appendix R), has a positive effect on learning. Recent studies (see Rebetez et al., 2010; and Wong, Leahy, Marcus, & Sweller, 2012) also suggest a positive effect of animations over static pictures. However, other research argues against assuming automatic benefits
of the use of animations on learning. Firstly, the use of complex animations may increase learners’ cognitive load and interfere with their learning (Rasch & Schnotz, 2009; Scheiter & Gerjets, 2010; Tabbers & de Koeijer, 2010). Secondly, animations may reduce the extent to which learners engage with the material to be learnt if they are distracted by details that are not relevant (Lowe, 1999, 2003). Thirdly, because dynamic animations depict continuous processes, the ‘transient nature’ of such representations may prevent learners from focusing on or revisiting particular parts of the process (Rebetez et al., 2010; Tversky et al., 2002). A recent study by Wong et al. (2012) provides further evidence of the effect of animations. These researchers found that shorter animations appeared not to induce heavy cognitive loads, but that longer animations appeared to overload working memory, thereby hindering learning. It needs to be noted, however, that some researchers (e.g. Ploetzner & Lowe, 2012; Tversky et al., 2002) question the methods used when investigating the effects of animations on learning. Ploetzner and Lowe pointed out fundamental problems with the diversity of animations used in research, which “make it difficult to compare the results and to formulate valid generalizations across different studies” (Ploetzner & Lowe, 2012, p. 781). Tversky et al. point out that some of the research evidence for a positive effect of animation on learning has been carried out using situations where the animated and non-animated versions of material were not comparable. For example, in some cases the “animation condition allowed interactivity while the static condition did not, so that benefits may be due to interactivity rather than animation” (Tversky et al., 2002, p. 253). In other cases these researchers found that the graphics in the animation situation were superior to those in the non-animated situation. The findings of Tversky et al. underscore the importance of reading research results critically, and interpreting them with caution.

It appears that the mere inclusion of animations in multimedia software is not sufficient to ensure that they will promote meaningful learning. Recently, there has been a trend to introduce interactivity into animations (Rasch & Schnotz, 2009) as one of the ways to overcome the high cognitive load imposed by learners having to “integrate textual and pictorial information during a restricted amount of time” (Tabbers & de Koeijer, 2010, p. 441). Allowing learners to interact with an animation means they can control the pace of the animation. Such control could reduce the cognitive load and contribute to enhanced learning (see the ‘interactivity principle’ in Appendix S) (Mayer & Chandler, 2001; Mayer, Dow, & Mayer, 2003). However, while there has been empirical evidence for a positive effect for learner control of animations (see Hasler & Kersten, 2007; Schwan & Riempp, 2004), other research has produced conflicting results about whether allowing learners to control the pace of animations enhances their learning (see Lowe, 1999). In addition to allowing learners to control the pace of animation, other methods have also been explored to enhance the potential benefits animations offer learning. These methods include the use of cues such as arrows to show the direction of movement of objects in dynamic animations (Boucheix & Lowe, 2010; Imhof, Scheiter, Edelmann, & Gerjets, 2013) and the use of colour to focus learners’ attention on important objects (Boucheix & Lowe, 2010).

**Interactivity**

The literature suggests that there is some ambiguity around how to define interactivity within the context of human-computer interactions, and the conditions under which interactivity enhances learning with multimedia software. Some researchers (e.g. Evans & Gibbons, 2007; Sims, 1997) use a purely systems-based approach when defining interactivity. According to these authors the degree
of interactivity is an affordance of the software and depends on the underlying design of the software. These authors refer to multimedia software as ‘interactive’ if the software includes computer-initiated interactivity and as ‘non-interactive’ if there is little or no computer-initiated interactivity. Such a functional approach to defining interactivity places the emphasis on the affordances of the system “to engage the learner in behavioural activities” (Domagk et al., 2010, p. 1025). Other researchers (e.g. Domagk et al., 2010; Kalyuga, 2007; Moreno & Mayer, 2007) find the functional approach limited and prefer to approach the concept of interactivity from the psychological perspective of the cognitive processes learners use when engaged in different types of interactivity. Domagk et al., however, claim that the psychological approaches “do not differ substantially” (Domagk et al., 2010, p. 1026) from the functional approach to interactivity. Kalyuga combines the system-based and learner-control perspectives by acknowledging that “learner control represents an important feature or dimension of interactive learning environments” (Kalyuga, 2007, p.392). Interactivity thus appears to be a two-way process in which the learner and the software respond to each other, providing the software has been designed to facilitate such interaction. In terms of different levels of interactivity, researchers (e.g. Kalyuga, 2007; Moreno & Mayer, 2007) appear to agree that, on the “continuum of interactivity” (Moreno & Mayer, p. 311) multimedia software providing predefined feedback (e.g. yes/no answers) offers low interactivity. Higher levels of interactivity involve the system providing varied responses depending on the actions of the user, e.g. “manipulating a simulation by entering specific values for input parameters” (Kalyuga, 2007, p. 393). These responses are, however, not tailored to learners’ previous responses. The highest levels of interactivity involve communication between learners and software, which Kalyuga describes as “flexible, non-predetermined iteratively-adapted responses to learners’ live queries” (Kalyuga, 2007, p. 393).

According to the constructivist model of learning, learners learn better when they are actively involved in their own learning, which suggests that learning should be enhanced when learners use interactive rather than non-interactive multimedia systems. Research evidence on the effect of interactivity in learning with multimedia, however, is also conflicting. Some studies suggest that learner interaction improves learning. Mayer et al. (2003) found direct evidence for the positive effect of interactivity when they included learner interaction in a lesson. The interactivity, which involved learners selecting the timing and order of explanations about the working of the electric motor, contributed to higher scores in problem-solving tests. Evans and Gibbons (2007) also reported a positive effect for interactivity. In their study 33 learners were divided into two groups and given a multimedia lesson on how to operate a bicycle pump. One group was given an interactive version of the lesson, while the other was given a non-interactive version. The researchers reported that the students given the interactive lesson performed better on problem-solving tests than the group given the non-interactive version. However, one of the features included in the interactive version was learner control of pace of presentation, which itself contributes to a reduced intrinsic cognitive load (see segmenting principle in Appendix R). The successful interactivity effect claimed by Evans and Gibbons could thus be due to other factors and not entirely to the presence of interactivity in the lesson. In another study, Tabbers and de Koeijer (2010, p. 444) tried to “replicate the interactivity effect found by Mayer and his colleagues” in the Mayer et al. (2003) study discussed above, and in an earlier study by Mayer and Chandler (2001). Tabbers and de Koeijer reported a positive effect for interactivity on learning with animations, despite learners spending more time on the interactive tasks than the non-interactive versions. The study by Moreno and Valdez (2005), however, suggested that interactivity could hinder
learning. These researchers found that allowing students to organise a series of frames on the formation of lightning (interactive group) had a detrimental effect on learning compared to the users in the non-interactive group which did not organise the frames. However, Domagk et al. (2010) attribute the conflicting results to the different definitions of interactivity used by different researchers.

Some researchers regard navigation as a type of interactivity (Moreno & Mayer, 2007). ‘Navigation’ refers to users’ ability to find their path through a software programme using the “labelling” (Rosinski & Squire, 2009, p. 158) provided on the software interface (see the interface design principles which can facilitate learners finding their way through multimedia content, in Appendix P). Lawless and Brown (1997), and Puntambekar and Stylianou (2005), believe that multimedia software can facilitate learners choosing their path through multimedia content using hyperlinks. According to these researchers allowing learners to choose their path through content fosters meaningful learning by requiring learners to potentially consider (hence the potential for active engagement) the path they follow through a programme. With reference to the potential for flexible navigation pathways in multimedia to engage learners and promote meaningful learning, Puntambekar and Stylianou point out the following:

For hypertext systems to be valuable in educational settings, learners need to negotiate what is important to them and what they should consider reading next, which requires them to regulate their navigation and learning. (Puntambekar & Stylianou, 2005, p. 452)

However, the requirement to regulate their navigation and learning when choosing their own path through a software programme could increase learners’ cognitive load and hinder meaningful learning (Rosinski & Squire, 2009), especially if the navigation system is difficult to negotiate. The literature suggests a number of ways to reduce learners’ cognitive load when navigating a programme, including the use of site maps (see Advanced principles of multimedia learning in Appendix S). Site maps provide users with an “overview of the site’s areas in a single glance” (Nielsen & Norman, 2008, p. 1). Nielsen and Norman, after comparing the results of two studies conducted seven years apart, believe that although site map usage in the studies was low (27% of users in the first study and 7% in the second), a clearly labelled and easy to use map of the site could be useful to people who do use them.

5.6 A MODEL FOR THE CONTEXT-BASED EVALUATION OF INTERACTIVE MULTIMEDIA

Reeves and Marlino made the following statement in the introduction to a tutorial on evaluating interactive software packages:

No single evaluation strategy can provide the complete picture of the effectiveness and impact of interactive learning. To conduct a comprehensive evaluation of interactive learning requires a “triangulation” approach whereby multiple models and procedures are applied. (Reeves & Marlino, 1997)

In keeping with the idea of software evaluation requiring a triangulation approach using multiple models and approaches, Reeves describes four “facets” or aspects of evaluation that designers should carry out in the “context of developing technology based learning products” (Reeves, 1993, p. 15.1).
• **documentation evaluation** – designers should evaluate how resources have been used during the software development process, so that they can account for resources expended (Reeves, 1993).

• **formative evaluation** – designers should evaluate the product at various stages during its development to assess whether aspects of the package (e.g. icon design) can be improved (Reeves, 1993).

• **summative evaluation** – Reeves refers to this aspect of evaluation as “effectiveness evaluation” (Reeves, 1993, p. 15.1) because it deals with the developers’ assessment of how effective the final product is, but only in the “short-term context” (Reeves, 1993, p. 15.4), i.e. before the package is made available commercially and used within specific educational institutions. Summative evaluation can be summed up as designers evaluating how their product is received and whether it is used in the way they intended it to be.

• **impact evaluation** – designers should evaluate the impact of their package on its target group to assess whether “the knowledge, skills and attitudes learned in the context of instruction transfer to the intended context of use” (Reeves, 1993, p. 15.4). This type of evaluation may involve a few pilot studies in classrooms for designers to assess whether their software package does enhance learning.

The four types of evaluation described above are typically meant to be carried out by designers before software is used for teaching and learning purposes. However, these evaluations are conducted external to the context of use of the software, by designers and developers. Once the software has been purchased for use, its suitability for use within a specific teaching context (e.g. a school) should be evaluated to ensure that it meets the specific requirements of that context. The type of evaluation of the software that teachers who will use the software would need to conduct would have a similar purpose to the impact evaluation conducted by designers during the development phase: it would focus on the extent to which the software package enhances learning within the context of use.

It thus appears that the ‘lifespan’ of a software package can be divided into two distinct phases. The first phase involves the development of the software package. The second phase occurs after the software has been purchased for use. The junction between the two phases is the point at which the software package becomes commercially available. The first phase usually takes place within what I refer to as the ‘design environment’. The design environment is usually external to the context within which the software is to be used for teaching and learning purposes, although software may be designed within the user environment. For most South African schools the design environment would be external to the user environment. The second phase constitutes the phase during which the software is used within a specific school or educational setting – the ‘user environment’. During the development phase, in the design environment, the onus of evaluation falls on the software designers. Once software is purchased for use within a specific user environment, the onus for evaluating it falls on the teachers who will use the software.

In the absence of a single unifying theory to guide my research (conducted in the South African context), I developed a model for the evaluation of multimedia instructional software. The model proposed here (see Figure 32, on the next page) is a context-based one that takes into account the
two distinct contexts of software development and software use which exist in most South African schools. The model distinguishes between the external ‘design’ environment and the internal ‘user’ environment (see Figure 32) which existed in the context of my study. Designers are situated within the ‘design’ environment and fulfil dual roles as software developer and evaluator (see Figure 32). The internal ‘user’ environment, typically a school, is represented in the model as an inner circle, and teachers and learners are role players found inside the ‘user’ environment (see Figure 32). The triangle connecting the designer, learner and teacher is taken from the perspectives interactions paradigm (Squires & McDougall, 1994). As in the perspectives interactions paradigm the bi-directional arrows between designers, teachers and learners represent the interactions between these three role players. These interactions centre around software packages designed by the designer, which are used by the teacher and which are meant to have an impact on the learners. The solid arrows from designers to teachers and learners represent the direct effect the designer has on teachers and learners via the design features of the software. The broken arrows from teachers and learners to the designer represent the indirect links they have with the designer, who might have received feedback from a sample or samples of teachers and learners through summative and impact evaluations conducted during the software development phase but who is unlikely to have had contact with the teacher and learner in specific educational institutions.

Figure 32. A model for context-based evaluation of software
The model for context-based evaluation considers the extrinsic factors (originating within the design environment) and intrinsic factors (arising within the user environment) which could affect the effectiveness of a software package in enhancing learning. Cognitive theories of multimedia learning (see pages 69-71) underscore the importance of the design features of a software package in influencing learning. Design features (e.g., pedagogical design principles) are extrinsic factors because they are under the control of the designer and typically occur outside the ‘user’ environment (see Figure 32). The design features impact on the ‘user environment’ because they constitute the features which determine the capacity of the software package to enhance learning. It is these design features of the software package teachers should evaluate before using it (hence the design features impinge on the circle representing the user environment in Figure 32). The extrinsic factors are, however, not the only ones that affect the effectiveness of the software in enhancing learning. According to Squires and McDougall (1994) when software is being evaluated for use in a specific educational context, technical features alone (such as interface design) will not guarantee that effective learning will occur, because factors originating within the context of use and features of the learners can have an impact, and therefore need to be considered. I refer to factors arising within the user environment which could affect the effectiveness of software to enhance learning as ‘intrinsic’ factors. The ‘intrinsic’ factors have not been included in the model because the model focuses on evaluating multimedia instructional packages and not on their impact.

I propose that the model for context-based evaluation of software be used as follows:

- The extrinsic factors which affect the ability of software to enhance learning should already have been evaluated by designers, using multiple approaches such as document evaluation, formative evaluation, summative evaluation and impact evaluation. Although the evaluations conducted during the development phase should be used to inform a broad range of decisions which software developers have to make (e.g., about funding, marketing, possible training in the use of the package), they should include evaluations of how well the software design meets the types of design principles given in Appendices P, Q and R (represented by extrinsic factors 1, 2 and 3 in the model). Where software has been designed to meet the requirements of a specific curriculum (extrinsic factor 4 in the model), this should also be evaluated.

- Teachers, as role players planning to use the software in the user environment, should evaluate the potential of the software to enhance learning within their specific context. This is why I have referred to the teachers as ‘evaluators and users’ in the model. Learners, even though they will ultimately be impacted on by the use of the software (and are therefore included as role players in the model), are not likely to be in a position to evaluate the overall worth of a software package for use within a specific context, but can evaluate certain design features like the use of icons or the usability of the interface. The teachers’ version of an ‘impact evaluation’ would require that teachers evaluate the design features which the designer has chosen to include in the software package so that they can assess the ‘usability’ of the software within their particular situation. Such an ‘impact evaluation’ would typically also focus on how well the software design meets the principles given in Appendices P, Q and R (extrinsic factors 1, 2 and 3 in the model) as well as on how well the software design meets the requirements of their local curriculum (represented by extrinsic factor 4 in the model). Beyond
this ‘impact evaluation’ of the software, teachers would have to evaluate other factors intrinsic to their context which could impact on their use of the software to enhance learning.

In this section I discussed the perspectives interactions paradigm (which approaches software evaluation from the perspectives of the main role players in software use) and theories of cognitive architectures for multimedia learning, which I used to derive a comprehensive set of design principles for multimedia software. I combined the concept of the role players from the perspective interactions paradigm with the design principles to develop a model which teachers could use to guide context-based evaluations of interactive multimedia packages. I used this model as a teacher evaluating the design of a software package within my particular context, that is, within the context of my specific curriculum requirements, the grade I intended teaching, and the content I intended teaching. I used it to develop a series of four open-ended checklists, one for each of the extrinsic factors given in the model, which I then used to evaluate the design of the software package.

5.7 METHODS FOR THE EVALUATION OF THE EDUROM PACKAGE

This section describes the sections of the software package selected as samples for the evaluation and the development of the four open-ended instruments used to evaluate the package.

5.7.1 Sampling relating to the software package

One of the aims of the study was to investigate the extent to which the software package could support South African teachers struggling to implement curriculum changes and also being required to teach new content, as in the case of Life Sciences teachers. The new Life Sciences content related to teaching biodiversity. I thus had to select relevant sections the package which would form the sample.

An overview of how the content in the package was organised follows, as this allows a better understanding of the relationship between different parts of the package, and introduces the names used in the package to refer to different sections of the content.

Figure 33 (on the next page) shows a section of the contents page of the software package from which I selected the content related to biodiversity, in my study. The package consists of 13 units, also referred to by the developers as ‘didactics’, which are represented on the left of the content screen by pictures numbered with Arabic numbers (1, 2, 3, etc.) and in the centre of the screen with text names in bold white font, numbered using Roman numerals (I, II, III, etc.), which can be viewed by scrolling down the list. Each ‘didactic’ contains a number of topics, with the topics following on numerically from the topics of the previous didactic. There are a total of 136 topics. Each topic is presented across a number of screens, with each screen having its own heading. Each of these main screens (as they will be referred to in this study) may have any number of sub-screens, which are usually accessed from the main screen.
Figure 34 shows the relationship between the topics, the didactics and the screens. The term ‘didactic’ is only used on the main contents screen for the package. In the rest of the package, notably the main screen for each topic, the term ‘unit’ is used instead of ‘didactic’. I will use the term ‘unit’ in this dissertation.

Figure 33. A section of the contents page of the courseware

Figure 34. The relationship between the units, topics and screens in the software

Five topics in the software package were found to have content relevant to biodiversity. Figure 35 (on the next page) outlines the structure of the content of the software package with the topics related to biodiversity highlighted in green. These five topics constituted the sample for the software evaluation phase.
5.7.2 The features of instructional software design investigated in this study

Any software package is the sum of a number of underlying design features which together contribute to the overall effectiveness of the package. This study used the design features from the model proposed in Figure 32 (see page 146) to evaluate the software, as represented graphically in Figure 36, on the next page. One of these features, pedagogical design, has two components (see Figure 36).
Figure 36. The features of instructional software design investigated in this study

5.7.3 The research instruments

Five data-collecting instruments were developed to evaluate the features of software design shown in Figure 36. All instruments were validated by my supervisor.

While each of the instruments is called a ‘checklist’, these instruments are modified versions of traditional checklists. Checklists usually involve a closed-format type of questionnaire with a list of options from which the person completing the list literally ticks one or more alternatives (Schumacher & McMillan, 2010; Mertens, 2005). Checklists may include a rating scale, which involves making a value judgement about a product (Fraenkel & Wallen, 1990). The main advantage of checklists is that they are usually quick to complete. A disadvantage of using traditional checklists is that they typically generate only numerical data and usually, even when they include a rating scale, do not offer any insight into why users chose a particular option. To overcome this shortcoming the instruments used in this study were modified so that, in addition to checklist-like categories, they contained an extra column in which open-ended (qualitative) comments could be made by the evaluator. The addition of such comments provided evidence for my choices in the checklist, thereby contributing to improved validity of the findings. These two aspects contributed to a more comprehensive evaluation of the software than could be arrived at by merely noting the presence or absence of features. Unlike traditional checklists, the ‘open-ended checklists’ used in this study thus generated both quantitative and qualitative data.

Development of the Curriculum Requirements Checklist

I have previously made reference to the claims made by the software developers about the suitability of the software for the new curriculum when the software was marketed in South Africa (see page 129). To evaluate the claim that the software is the answer to the new curriculum, I designed a Curriculum Requirements Checklist to evaluate the extent to which the software promotes the requirements of the new South African curriculum in the five software topics which contain content on biodiversity. An example of the Curriculum Requirements Checklist is shown in Appendix T.

The new curriculum has nine requirements (as outlined by Sanders & Kasalu, 2004). Although these nine requirements applied to the General Education and Training band (Grades 1 to 9), the
requirements extend to the Further Education and Training band (Grades 10 to 12). The nine requirements are listed below:

- Education should be outcomes-based.
- The curriculum content should be relevant to learners.
- Lessons should be activity-based.
- Teaching should be learner-centred.
- The teacher should be a facilitator of learning.
- Continuous assessment should be applied.
- Teaching should focus on the development of skills
- Group work should be promoted.
- Learning should be integrated across learning areas.

Two of the nine requirements were not included in the *Curriculum Requirements Checklist* because they were considered inappropriate for the task:

- *The teacher should be a facilitator of learning* was excluded because the focus of the evaluation was on the design of the software package and not on how it would be used in a teaching situation.
- *Learning should be integrated across learning areas* was excluded because it is less relevant to the Further Education and Training level (where the package was being used) than at the General Education and Training level (for which some of the curriculum requirements seem to have been designed when the new curriculum was first implemented. The new curriculum re-organised the subjects of the previous curriculum into *learning areas* for the classes of the General Education and Training phase (Grades 0 to 9), and teachers were required to integrate teaching across learning area boundaries. Within the Further Education and Training band there is less emphasis on integration between the subjects because of the difficulty of integrated teaching where different teachers are teaching different subjects.

The *Curriculum Requirements Checklist* developed for the software evaluation is divided into seven sections, one for each curriculum requirement evaluated. Within each of the seven sections questions based on the distinguishing features of each curriculum requirement (as spelled out by Sanders & Kasalu, 2004) were formulated to allow an evaluation of how well the software meets that requirement. Two of the seven curriculum requirements included in the checklist require a discussion of the rationale behind the questions used in the checklist:

**Curriculum requirement 1: Education should be outcomes-based (Department of Education, 1997)**

To evaluate this curriculum requirement, I needed to decide which of the sets of outcomes to focus on. The new curriculum had seven *critical* and five *developmental outcomes* that were inspired by the Constitution of the Republic of South Africa (spelled out in Appendix U). I decided not to use the
critical and developmental outcomes in my evaluation because they are too broad in their application. Muller (1998, p. 180) described the critical outcomes as “extremely broadly framed”. The critical and developmental outcomes apply to all subjects and across all grades, meaning that they are not specific enough to measure and hence to evaluate in the subject-specific software I was investigating. The broad application of the critical and developmental outcomes would also mean that these outcomes could be inferred in virtually anything taught.

Up to and including 2004, the outcomes for the new curriculum also included a set of specific outcomes for each learning area of the General Education and Training band (Grades R-9). The nine specific outcomes for the Natural Sciences (outlined in Appendix U) were replaced, in practice, in 2005, by three learning outcomes, although officially, these were only intended for implementation in 2006 (see Appendix U for the revised outcomes). The number of outcomes was reduced because teachers had found it too difficult to cope with so many different outcomes. The new learning outcomes were simply a reformulation of the existing specific outcomes, combining and condensing them into three broader outcomes. Table 17 shows the different types of outcomes⁶ and when they were implemented.

### Table 17. The different types of outcomes and when they were implemented

<table>
<thead>
<tr>
<th>Type of outcome</th>
<th>Duration of implementation</th>
<th>Level of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical outcomes</td>
<td>1998 to present</td>
<td>Across all learning areas and subjects and for all grades</td>
</tr>
<tr>
<td>Developmental outcomes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific outcomes</td>
<td>1998 to 2004 (in practice)</td>
<td>Specific to learning areas (GET band) and to subjects</td>
</tr>
<tr>
<td>Learning outcomes</td>
<td>2005 to 2011</td>
<td></td>
</tr>
<tr>
<td>Aims</td>
<td>2012-2014, and ongoing</td>
<td></td>
</tr>
</tbody>
</table>

In this evaluation I used the terms applicable to the FET National Curriculum Statement at the time, viz. the specific outcomes and learning outcomes. The specific outcomes and learning outcomes represented an attempt to make the critical outcomes and developmental outcomes more specific for a particular content area (see Table 18 for a comprehensive linkage of the outcomes⁷). Muller (1998) believes that assessment is likely to focus on the specific outcomes because he finds it difficult to see how the critical outcomes would be assessed. The specific outcomes and learning outcomes are more suitable to focus on in an evaluation because they are meant to be specific to a subject and would thus be easier to measure.

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⁶ The learning outcomes are no longer referred to by this name in the new CAPS documents implemented in 2012. The term ‘outcomes’ has been abandoned, to be replaced by ‘Aims’.

⁷ Whilst attempting to relate the specific and learning outcomes to the critical outcomes and developmental outcomes I came across a table in the Guidelines for Life Sciences learning programmes of the National Curriculum Statement (Grades 10-12), linking the various outcomes to each other. The linkage provided by this table appeared incomplete because it showed a limited linkage between the outcomes. On closer scrutiny of the relationships between the outcomes, I found that each of the Further Education and Training band learning outcomes is linked to all of the critical outcomes and many more of the developmental outcomes than was represented in the table in the Department of Education document, and have reflected these additional linkages in Table 18.
Table 18. Linkage of outcomes required by the National Curriculum Statement for Life Sciences (adapted from Department of Education, 2002)

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>Critical Outcomes</th>
<th>Developmental Outcomes</th>
<th>Specific Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Outcome 1</td>
<td>1, 2, 3, 4, 5, 6 &amp; 7</td>
<td>1, 2 &amp; 4</td>
<td>1, 3 &amp; 5</td>
</tr>
<tr>
<td>Learning Outcome 2</td>
<td>1, 2, 3, 4, 5, 6 &amp; 7</td>
<td>1, 4 &amp; 5</td>
<td>2 &amp; 7</td>
</tr>
<tr>
<td>Learning Outcome 3</td>
<td>1, 2, 3, 4, 5, 6 &amp; 7</td>
<td>1, 2, 3, 4 &amp; 5</td>
<td>4, 6, 8 &amp; 9</td>
</tr>
</tbody>
</table>

I decided to focus on the learning outcomes rather than the specific outcomes in my evaluation, based on the timing of the evaluation. The software package evaluated for this study was purchased in 2004, so any attempt by the software developers to address outcomes could only have been targeted at addressing the critical outcomes, developmental outcomes and the specific outcomes for a learning area (since these outcomes were in place at that time, as shown in Table 17, see previous page). Having eliminated the critical and developmental outcomes as unsuitable for use in this study, this left the specific outcomes. The software evaluation, however, was conducted after 2005, when the learning outcomes had replaced the specific outcomes. Since teachers using the software post-2004 would be using learning outcomes and not specific outcomes in their planning, it seemed more appropriate to use the learning outcomes in my evaluation. While this may seem unfair to the designers, the links between the specific outcomes and the learning outcomes mean that evaluating the learning outcomes could be considered valid as part of a usability study.

Curriculum requirement 2: Lessons should be activity-based (Department of Education, 1997)

Evaluating the curriculum requirement that lessons be activity-based required a system for classifying different activities. I adapted a system developed by Mashalaba and Sanders (2003) for classifying textbook activities (see Appendix V) by using the last two of three categories of activities from the Mashalaba and Sanders system. The first category in their classification system was omitted as it deals with practical activities like microscope work and field work and was deemed not applicable to computer work. The second category deals with communication activities like reading and writing tasks. This category was broadened for use with computers by adding a further type of task into the existing sub-category oral tasks, that of “learners reading into a microphone when using a computer”. The third category in the Mashalaba and Sanders classification system refers to text-based activities like review tasks, translation activities and completion tasks. This category was broadened to include “classification tasks” in the sub-category analysis tasks (see Appendix V).

When completing the Curriculum Requirements Checklist I used a combination of qualitative and quantitative data. Five of the seven sections of the checklist are purely qualitative. I completed these by describing how the curriculum requirement had been met or not met in the software. Two sections allowed quantitative data to be collected: that lessons to be activity-based and that continuous assessment should be applied. Where quantitative data was collected a summary was made based on an analysis of the data to facilitate a comparison across the five software topics being evaluated.

Developing the Content Coverage Checklist

Before developing the instrument for evaluating the software coverage of biodiversity, I had to decide how I would approach the subject matter. As pointed out by Shulman
...to think properly about subject knowledge requires going beyond knowledge of the facts or concepts of a domain. It requires understanding the structures of the subject matter… (Shulman, 1986, p. 9).

Schwab (1978) believed that teachers could approach the structures of a subject substantively and syntactically. The substantive structures refer to the different ways of organising the facts for a subject into the basic concepts and principles of that subject (Schwab, 1978). The syntactic structures refer to the “different methods of verification and justification of conclusions” (Schwab, 1978, p. 246). Shulman (1986, p. 9) describes the syntactic structures of a discipline as the “set of rules” for deciding the validity of claims made within that subject area. The substantive and syntactic components of content knowledge are shown in Figure 37. Both substantive and syntactic aspects of the content knowledge relating to biodiversity were evaluated in this study. The evaluation of the substantive content focused on the facts, concepts and principles relating to biodiversity and the relationships between these fundamental ideas. The content dealing with the principles of biological classification was used as the syntactic content for the topic biodiversity because it is these principles are used to interpret data for the section of content on biodiversity.

The evaluation of the content coverage in the software package required an evaluation of the adequacy of coverage as well as an evaluation of the suitability of the language used to convey the content. The Content Coverage Checklist developed for the study and shown in Appendix W therefore had two sections: one to evaluate the suitability of the content covered and the second to evaluate the use of language used in the software for teaching.

### Figure 37. The substantive and syntactic components of content knowledge

- **Substantive content**
  - facts
  - concepts
  - principles
  - relationships

- **Syntactic content**
  - principles of inquiry associated with a discipline
  - values inherent in discipline

To evaluate whether the content coverage was adequate I identified what content is needed to comprehensively cover the section of work biodiversity.

- In the National Curriculum Statement for Life Sciences (Department of Education, 2005) the section of work on biodiversity falls within the knowledge area **Diversity, change and continuity**. Much of the content within the knowledge area **Diversity, change and continuity** is new to the South African Further Education and Training curriculum, having been added in 2006. This makes it difficult for teachers to be certain of what content to include to meet Learning Outcome 2. Learning Outcome 2 deals with accessing content (Assessment Standard 1), interpreting content (Assessment Standard 2) and applying content knowledge (Assessment Standard 3) (see Appendix U). Table 19 shows the content as stipulated in the National Curriculum Statement for Life Sciences (Department of Education, 2005) for the knowledge area **Diversity, change and continuity** for Learning Outcome 2, across the three grades included in the Further Education and Training band (Grades 10 -12). This study focuses on the Grade 10 level
because that is where the software was being used. The content to be dealt with in Grade 10 has been highlighted in green in Table 19.

Table 19. Main topics identified in the National Curriculum Statement for biodiversity
(Department of Education, 2005)

<table>
<thead>
<tr>
<th>Grade 10</th>
<th>Grade 11</th>
<th>Grade 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>• biodiversity of plants and</td>
<td>• population studies, characteristics of</td>
<td>• origin of Species [sic]</td>
</tr>
<tr>
<td>animals and their conservation</td>
<td>populations, characteristics of populations,</td>
<td>• evolution theories, mutation, natural</td>
</tr>
<tr>
<td>• significance and value of</td>
<td>population growth, fluctuations, limiting</td>
<td>selection, macro evolution and speciation</td>
</tr>
<tr>
<td>biodiversity to ecosystem</td>
<td>factors</td>
<td>• fundamental aspects of fossil studies</td>
</tr>
<tr>
<td>function and human survival</td>
<td>• social behaviour - predation, competition,</td>
<td>• cradle of mankind - South Africa?</td>
</tr>
<tr>
<td>• threats to biodiversity</td>
<td>• managing populations</td>
<td>• biological evidence of evolution of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>populations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• popular theories of mass extinction</td>
</tr>
</tbody>
</table>

• The National Curriculum Statement provides no detail of how the content outlined in Table 19 should be expanded. I expanded the content to give the content shown in Table 20 by making the following changes:

  – **Adding content.** I added **consequences of loss of biodiversity** to the section **Threats to biodiversity** as was done in a textbook (Bezuidenhout, Clark, Engelbrecht, & Wilson, 2005) which was judged to closely follow the stipulations of the National Curriculum Statement. Two reference books also included this content in their sections on biodiversity (Boyle & Senior, 2002; Galbraith, 1993).

  – **Rearranging the content into a more logical arrangement.** The section on conservation has been shifted from the section of work entitled **biodiversity of plants and animals and their conservation** to a section with which it links better, **significance and value of biodiversity to ecosystem function and human survival**.

Table 20. Outline of the expanded content that should be included in the knowledge area **Diversity, change and continuity** at Grade 10 level

<table>
<thead>
<tr>
<th>Section of work</th>
<th>Content that should be included to comprehensively cover biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>• biodiversity of plants and animals (and their</td>
<td>• definition of the term ‘biodiversity’</td>
</tr>
<tr>
<td>conservation)</td>
<td>• levels of biodiversity: genetic diversity, species diversity and</td>
</tr>
<tr>
<td></td>
<td>• ecosystem diversity</td>
</tr>
<tr>
<td></td>
<td>• five-kingdom classification of living species</td>
</tr>
<tr>
<td>• Significance and value of biodiversity to</td>
<td>• value of diversity</td>
</tr>
<tr>
<td>ecosystem function and human survival;</td>
<td>• definition of the term ‘conservation’</td>
</tr>
<tr>
<td>conservation of biodiversity (moved to this section)</td>
<td>• need for conservation</td>
</tr>
<tr>
<td>• Threats to biodiversity</td>
<td>• what is meant by ‘loss of biodiversity’</td>
</tr>
<tr>
<td></td>
<td>• consequences of loss of biodiversity (added)</td>
</tr>
<tr>
<td></td>
<td>• threats to biodiversity: habitat loss; invasive species;</td>
</tr>
<tr>
<td></td>
<td>• overconsumption (over hunting and overgrazing);</td>
</tr>
<tr>
<td></td>
<td>• monoculture</td>
</tr>
</tbody>
</table>

Sources: Galbraith (1993); Boyle & Senior, 2002; Bezuidenhout et al. (2005); Department of Education (2005)
Chapter 5: Evaluation of the EduRom multimedia software package

The expanded content in Table 20 was used as a basis for compiling a list of terms and concepts which should be covered in the section Diversity, change and continuity at Grade 10 level. The list of terms and concepts compiled is shown in Appendix X. Once I had determined what content should be covered, I developed the Content Coverage Checklist shown in Appendix W. The checklist is divided into two sections. The first section contains questions relating to the suitability of the content used based on the terms and concepts in Table 20.

The second section in the Content Coverage Checklist evaluates the suitability of the terminology and language used in the software to convey the content on biodiversity. I consulted two sources to compile a set of language-related evaluation criteria:

- a set of guiding criteria for selecting textbooks as issued by the Department of Education (Department of Education, 2003)
- a set of guidelines for designing effective curriculum materials, developed for publishers by a consultant they were using (Sanders, 1993).

From these sources I extracted the language-related guidelines and constructed the two criteria included in the checklist to evaluate the suitability of the terminology and language used to convey the content.

The questions in the checklist (for both criteria) were answered using a rating scale of ‘good’, ‘fair’ and ‘poor’. Space was left for qualitative comments to explain each of the rating choices in the checklist. The instrument itself is shaded in green. The white areas show where I recorded my explanations.

Development of the Pedagogical Strategies Checklist

This section deals with the second aspect evaluated under “pedagogical design” of the software (see Figure 36, page 151). The Pedagogical Strategies Checklist (included as Appendix Y) is based on the framework of learning principles developed for use in this study and presented in Appendix Q. Pedagogical strategies which could be used to evaluate the software were derived from these learning principles. In developing the checklist

- two learning principles (Learning involves the construction of knowledge and Learning should be an active process) were combined into one pedagogical strategy. Active learning is likely to lead to knowledge being constructed, so it seemed logical to combine these two learning principles into a single strategy.
- three pedagogical strategies were derived from the learning principle that Assessment should be interwoven with teaching so that regular feedback can be given to learners. Assessment as a broad strategy to promote learning has many facets, so I divided this strategy into three parts to make my evaluation more objective.

The final checklist effectively consists of ten pedagogical strategies (three deal with assessment) (see Appendix Y). I completed the checklist by recording whether or not a particular strategy had been used in the software and, where applicable, whether or not the strategy had been used effectively. As with the other checklists, I added a qualitative comment on why a particular evaluation had been made.
**Development of the Interface Design Checklist**

The interface is where users interact with a software package. The combination of multiple media (text, images, animation, audio and video) on the user interface of multimedia software results in a complex combination of stimuli. Evaluating how effectively the interface design conveys messages to users is an essential component of evaluating a software package (Reeves & Harmon, 1993). Wurman (1989, cited by Brockmann, 1991) warned against thinking that

...looking good is being good. The disease of looking good is confusing aesthetics with performance. A piece of information performs when it successfully communicates an idea, not when it is delivered in a pleasing manner. Information without communication is no communication at all. It is an extremely common, insidious malady among graphic designers and architects to confuse looking good with being good. The cure obviously is to ask how something performs (Wurman, 1989, cited by Brockmann, 1991, p. 153).

As previously stated (see page 139), an evaluation of interface design requires consideration of the graphical design (look of the interface) and the navigational design (which refers to users’ ability to find their way through the package). For the purposes of this study, six categories of interface design elements were identified from the literature: navigational features, media use and integration, text design, screen layout, graphics and images, and use of colour. The series of guidelines developed using information from the literature for each of these categories of design elements (see Appendix P) was used to develop a qualitative checklist based on these design guidelines (see Appendix Z).

The questions in the Interface Design Checklist (see Appendix Z) were phrased so that they could be answered using yes/no answers. Such answers sometimes required quantification, e.g. *Is the number of words per line appropriate (not exceeding 8 – 10)?* A separate quantitative checklist (called the Frequency Count Checklist and shown as Appendix AA) was designed to record the number of times a particular design element occurred in a topic. In the example above the Frequency Count Checklist was used to record the average number of words per line for each screen in a particular topic, which then allowed the percentage of screens in that topic that violated the recommended guideline to be calculated. This value could then be compared across the five topics. The quantitative data obtained from the Frequency Count Checklist could then be used to arrive at a “yes” or “no” answer to the question in the Interface Design Checklist. Provision was made in the Interface Design Checklist to add comments explaining why a design guideline was considered to have been upheld or violated in the software.

Reeves and Harmon (1993) identified ten user interface dimensions that could be evaluated, but stressed that not all of their dimensions would necessarily be relevant to all multimedia packages. Appendix AB outlines the ten Reeves and Harmon dimensions, giving a brief description of each dimension and the reason for using or not using it in the evaluation of user interface design in this study. I found that some of their dimensions would be more applicable to other evaluation categories used in this study than to an evaluation of user interface design. For example, the “information presentation” dimension used by Reeves and Harmon in their rating tool evaluates whether the information contained in a software package is “presented in an understandable form” (Reeves & Harmon, 1993, p. 5). In this study the comprehensibility of the information in the software package was regarded as being dependent on the quality of the language used to convey the content and was
evaluated as part of the pedagogical design of the software (see page 157 in previous section) and was thus not included as an interface design dimension.

Two user interface dimensions used by Reeves and Harmon – “cognitive load” and “knowledge space compatibility” were excluded because they would be evaluated in other categories, leaving seven of the original ten dimensions of interface design. The dimension “overall functionality” was excluded because it seemed more appropriate to use this when evaluating the functionality of the software package as a whole. Five of the remaining six Reeves and Harmon dimensions were combined with the categories of design features in the Interface Design Checklist and arranged into a hierarchy of dimensions and sub-dimensions (see Figure 38). The Reeves and Harmon dimension “ease of use” was expanded to “ease of use of interface” and used as a summative dimension to deliver a final decision on the usability of the interface design in the software package. The “ease of use of interface” dimension is thus found on the highest tier of the hierarchy shown in Figure 38. The sixth remaining Reeves and Harmon dimension (“aesthetics”) has not been included in the hierarchy shown in Figure 38 because it was not present in the User Interface Checklist. Although this means that I have no objective basis for evaluating the “beauty and elegance” of the user interface, I will nevertheless deliver a comment on the aesthetics of the user interface based on a number of comments I have recorded in my journal from people who had seen the user interface but not necessarily used the package, and from my personal experience with using the software.

Figure 38. The hierarchy of dimensions and sub-dimensions of interface design features used in this study

Although some of the features in this section have been evaluated in other checklists, the evaluation reported on in this section is based on specific research-based principles which have been formulated for their effect on multimedia learning. I felt that it was worthwhile evaluating the software against these specific principles.

**Development of the Multimedia Design Checklist**

The Multimedia Design Checklist (see Appendix AC) is based on the framework of basic and advanced learning principles developed for use in this study from the work of a number of researchers, focusing strongly on features spelled out by Mayer (2005) in his book on multimedia learning. Basic guidelines for designers as to what technical features should be included in interactive
multimedia educational packages to enhance learning have been summarised in Appendix R, while advanced guidelines are given in Appendix S). The following multimedia principles were not used in the checklist:

- Two of the **basic** design principles (see Appendix R) were not evaluated:
  - The use of an on-screen character, which Mayer (2005) does not believe enhances learning, was not evaluated because the software package does not include this design feature.
  - The segmenting principle suggests that learners have control over the pace at which complex animated material is presented. The only animation in the five topics does not deal with complex material, so this principle was not used.

- Two of the **advanced** design principles (see Appendix S) were not evaluated:
  - The principle on guided discovery was omitted because the software package being evaluated is not a discovery-based multimedia environment.
  - The principle which aims to compensate for age-related declines in cognitive ability was not evaluated because the instructional multimedia software is being evaluated at Grade 10 level, where age-related cognitive decline is unlikely to occur.

The checklist (see Appendix AC) has a column which was completed by placing a tick if a particular multimedia strategy for enhancing learning was present in the software or a cross if the feature was absent. Provision was made for a comment to be added in the last column of the checklist to explain why a strategy was judged to be supported or not supported in the software package.

### 5.8 RESULTS AND DISCUSSION

#### 5.8.1 The extent to which the package addressed the requirements of the new curriculum

**Curriculum requirement 1: Education should be outcomes-based**

The completed *Curriculum Requirements Checklist* showing the extent to which the outcomes are addressed in the software package is included as Appendix AD. The findings for the extent to which the learning outcomes are addressed in the package are:

- **Learning Outcome 1.** The *EduRom* software does not promote Learning Outcome 1 because the software does not teach any investigative skills in the five topics. None of the investigative skills specified in the assessment standards for this outcome (e.g. planning investigations or analysing data) are taught in any of the five topics, nor are users required to use them.

- **Learning Outcome 2.** The wording for Learning Outcome 2 states that the learner should be able to access, interpret, construct and use Life Sciences concepts to explain phenomena relevant to Life Sciences. The verbs used in the wording of Learning Outcome 2 ("access", "interpret", "construct" and "use") are so broad that they could apply to a wide range of situations. For example, learners reading a book, viewing a poster, or watching a film are all
‘accessing information’. Similarly, the requirement that learners use Life Sciences concepts to explain phenomena relevant to Life Sciences is so broad that it could be applied to situations where learners use knowledge they already have. Based on the vague wording of Learning Outcome 2, it would have to be said that the software promotes the learning outcome because the software presents factual information new to learners and requires some interpretation of information (mainly involving interpreting instructions to be able to carry out activities). However, the outcome can only be said to be achieved at a very superficial level, and probably not in the spirit in which it was intended.

- **Learning Outcome 3** is as vaguely worded as Learning Outcome 2. It states that

  … the learner is able to demonstrate an understanding of the nature of science, the influence of ethics and biases in the Life Sciences and the interrelationship of Science, Technology, indigenous knowledge, the environment and society.

The outcome does not specify **how** learners will demonstrate their understanding of the nature of science, the influence of ethics and biases in the *Life Sciences* and the various interrelationships which are mentioned. Since it is not specified how this understanding will be demonstrated, it is difficult to evaluate whether the software promotes this outcome. Table 21 is a summary of which aspects of Learning Outcome 3 are covered in the five topics.

**Table 21. Summary of which aspects of Learning Outcome 3 are covered in the five software topics**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Nature of science</th>
<th>Science, technology and the environment</th>
<th>Indigenous knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – <em>How has man classified the world around him?</em></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>124 – <em>An ecosystem is a working organisation</em></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>132 – <em>Types of pollution</em></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>133 – <em>Species dying out</em></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>135 – <em>The nature necessary for living [sic]</em></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Based on the fact that each of the five topics includes information which can be related to some aspect of Learning Outcome 3, I have judged this outcome to have been targeted in the five topics evaluated, but, like Learning Outcome 2, Learning Outcome 3 can only be said to be achieved at a very superficial level.

**Curriculum requirement 2: Lessons should be activity-based**

Activity-based learning refers to learning where an activity is carried out which allows learners to construct knowledge (i.e. the activity leads to learning). An activity is taken to be an action or series of actions that the user is **directed** to perform.

An overview of the activities used across the five topics shows that they are limited both in the number and the types of activities (see Table 22 on the next page):

- The percentage of activities used per topic is low, ranging from activities on 8% of the main screens for Topic 124 to activities on 16% of the main screens for Topic 3.
• Only two types of activities are used out of more than 30 different types of activities which can be carried out using computers (see Appendix V for typology of activities that can be carried out on computer, adapted from Mashalaba and Sanders, 2003).

Table 22. Summary of the activities present in the five topics

<table>
<thead>
<tr>
<th>Topic</th>
<th>Number of activities</th>
<th>Number of main screens*</th>
<th>Types of activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – How has man classified the world around him?</td>
<td>4</td>
<td>25</td>
<td>• 3 classification activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• 1 read, listen and record</td>
</tr>
<tr>
<td>124 – An ecosystem is a working organisation</td>
<td>1</td>
<td>13</td>
<td>• 1 read, listen and record</td>
</tr>
<tr>
<td>132 – Types of pollution</td>
<td>1</td>
<td>10</td>
<td>• 1 read, listen and record</td>
</tr>
<tr>
<td>133 – Species dying out</td>
<td>1</td>
<td>10</td>
<td>• 1 read, listen and record</td>
</tr>
<tr>
<td>135 – The nature necessary for living</td>
<td>1</td>
<td>11</td>
<td>• 1 read, listen and record</td>
</tr>
</tbody>
</table>

*Activities are only found on the main screens, not on sub-screens.

A detailed analysis of the activities used in the five topics (see Appendix AE) reveals that while these types of activities may have had the potential to promote mental engagement and lead to the construction of knowledge, the way they are structured in the software negates this potential.

Examples of the two types of activities used in the five topics evaluated are shown so that the reader can better understand what the activities require learners to do. A read, listen and record activity is shown in Figure 39, on the next page.

The read, listen and record activities are little more than drill-and-practice activities, which do not require much mental engagement from learners. Problems with the design and functionality of the read, listen and record activities further reduce the possibility of this type of activity leading to learning. The activity is problematic because

• Learners are not told that that a microphone is needed for the activity. This means that learners may not have a microphone ready when they want to carry out the activity or they may not have access to a microphone at all.

• Even when a microphone is installed and functioning on the computer, the recording function in the software does not work.

• The mere act of clicking on the Record icon causes the tick to appear. The appearance of the tick does not seem to depend on whether the fact is correctly recalled or even recorded.

The read, listen and record activities are ineffective in promoting learning because:

• Learners are not explicitly required to check whether they have repeated the fact correctly, making the task meaningless.

• People typically accommodate +/- seven ‘bits’ of information in short-term memory (Miller, 1956). The length of the facts used in the activity would be difficult for anyone to memorise and then repeat (let alone Grade 10 learners).

• The language used is complex and likely to be difficult for Grade 10 learners to cope with.
The second type of activity used is a drag and drop activity. All three drag and drop activities (which are all found in one topic) involve classification tasks. An example of a classification task is shown in Figure 40.

There are no instructions telling users how to carry out the read, listen and record activities on the Remember screens. Through trial-and-error I found out that there are essentially three parts to the activity, which users access by clicking on the relevant icon:

- The Listen icon (arrowhead) to the left of a fact accesses an audio-byte of the fact being read out loud.
- The Record icon allows viewers to repeat the fact out loud into a microphone. When the Record icon is clicked the text for that fact disappears from the screen, so users are repeating the text from memory. At the same time a green tick appears to the right of the fact for which the audio was played. When the recording time is over the text reappears on screen.

Figure 39. A Remember screen showing a read, listen and record activity
Learners can complete this type of activity with minimal mental engagement by using trial-and-error to group organisms they are supposed to be classifying. Consequently these activities are unlikely to lead to learners constructing knowledge.

Neither of the types of activities used in the five topics can be said to promote activity-based learning.

**Curriculum requirement 3: Learning should focus on skills development**

Table 23, on the next page, summarises the evaluator’s comments from the Curriculum Requirements Checklist on the extent to which the five software topics promote skills development and shows that

- the software package does not teach any skills
- the absence of clearly stated outcomes (at all, let alone on skills) implies that the designers were not planning to meet the requirement that skills should be taught
- learners are only required to use lower-order cognitive skills in the five topics.
The software cannot be said to have met the requirement that learning should focus on the development of skills.

**Table 23.** Extracts from the completed *Curriculum Requirements Checklist* showing the extent to which the five software topics promote skills development

<table>
<thead>
<tr>
<th>Criteria for skills development in instrument</th>
<th>Evaluator’s comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skills to be taught or developed are <em>stated</em> in the outcomes.</td>
<td>No outcomes or goals were stated; therefore no skills to be taught were explicitly stated as outcomes.</td>
</tr>
<tr>
<td>Skills are explicitly <em>taught</em> in the five topics.</td>
<td>No skills are taught in the five topics.</td>
</tr>
<tr>
<td>Learners are required to <em>use</em> skills in the five topics.</td>
<td>Basing the evaluation on the skills taught to Biology/Life Sciences learners at senior level, learners were not required to use any skills in the five topics except comprehension and application of their knowledge. These skills qualify as lower order cognitive skills (according to Bloom’s taxonomy).</td>
</tr>
</tbody>
</table>

**Curriculum requirement 4: The curriculum content should be relevant to learners**

The question “When can content be considered relevant to learners?” is difficult to answer. A narrow interpretation of when content is relevant to learners might suggest that content is relevant only if it includes direct references to the South African context or to South African learners’ real life experiences, or can be linked to their prior knowledge. If the question of content relevance is addressed too narrowly learners will not be exposed to information that can expand their knowledge. A narrow interpretation of content relevance might also fail to make provision for learners having future interests and needs which may fall outside of the South African context. In addition, given the heterogeneous nature of South African society, it is virtually impossible to characterise a ‘typical’ South African learner in terms of learners’ real life experiences. For example, learners in the more affluent urban schools are likely to have very different life experiences to learners in rural farm schools. Evaluating the relevance of content thus requires a broader approach in which virtually all content can be regarded as being relevant unless learners cannot, for some reason, interpret the content and are therefore unlikely to appreciate the significance of the content.

A summary of the relevance of content in the five topics is included as Appendix AF.

When evaluating the relevance of content in the software I initially applied the most narrow perspective: the *Curriculum Requirements Checklist* looks for direct references to South African examples, direct references to South African learners’ real-life experiences, or content that could be linked to South African learners prior knowledge (based on Grade 10 level and what learners should have been taught in the General Education and Training phase according to the National Curriculum Statement for the *Natural Sciences*, which outlines the content for Grades 7 to 9). This narrow perspective provided the easiest way of identifying the most overtly relevant content. Any content not judged relevant against these criteria was then examined more closely to evaluate its relevance to South African learners.

Even using the narrow perspective of meeting the criteria for relevance most of the software content was found to be relevant to South African learners (see Appendix AF).
Most of the content is relevant to learners’ real life experiences and situations because it uses South African examples. However, a word of caution is needed. One of the examples used is of a lion. While lions occur in South Africa, most South Africans will not have seen a real lion. Most people, however, are likely to have seen photographs of lions. Television has played a significant role in making peoples’ ‘experiences’ wider, because it allows people to see images they might not otherwise have seen. Thus, South African learners’ ‘prior knowledge’ and ‘experience’ may be no different from children elsewhere in the world.

The linkage of content to learners’ prior knowledge was more difficult to judge. The software package does not specifically link any content to learners’ prior knowledge, except for references to software content in earlier topics in the package which learners may or may not have worked through. I therefore had to rely on what Grade 10 learners should have been taught in earlier grades. However, this was complicated by the widely differing content taught in Grades 8 and 9 across schools because the curriculum statement does not specify the content to be taught in each grade. Many schools choose what content they will teach in Grades 8 and 9, making it difficult to decide exactly what ‘prior knowledge’ a ‘typical’ Grade 10 learner should have. In the end I judged the ‘prior knowledge’ component of content relevance based on my personal experience of having taught Grades 8 and 9 in five different schools over a period of seventeen years. Fortunately, the software content was judged relevant based on the other two categories by which content could be made relevant, so that the ‘relevant’ decision was not based entirely on the linkage to prior knowledge.

The single instance where the content was judged not to be relevant to South African learners is found in Topic 3, which deals with classification. It involves a Russian nesting doll which is meant to represent the different taxonomic groups (see Figure 41).

The “Russian nesting doll” graphic is meant to support an audio insert which explains that each lower taxonomic group is smaller than the previous one. The graphic and the audio insert do not convey the increasing number of groups lower down the taxonomic hierarchy.

Figure 41. The Russian nesting doll graphic in Topic 3

The nesting doll analogy used in this graphic is likely to fall outside of learners’ experience for many countries, not only South Africa. Learners may not have the knowledge or experience of such dolls to understand that each doll can be opened to reveal a smaller one. Missing this background knowledge suggests users are unlikely to make the link to the idea of the taxonomic groups getting smaller down the hierarchy. The use of the nesting doll is, in any case, a poor analogy for the taxonomic hierarchy because although taxonomic groups become smaller down the hierarchy (which the graphic conveys),
they increase in number. The one-to-one relationship of the nesting dolls fails to make this point clear. If a graphic is used which may be understood by some learners but not by others, the concept being illustrated needs to be clearly explained, which is not the case with this software.

**Curriculum requirement 5: Group work should be promoted**

Collaborative learning is believed to enhance learning (Peers, Diezmann, & Watters, 2003; Vygotsky, 1978). The package does not specify the use of any collaborative or group activities. There is no use of communication activities\(^8\) like debates, role plays, presentations and group discussions, which could have been useful in promoting group work for teaching the topics dealt with. Unless the teacher assigns tasks to be carried out in groups, group work is unlikely to be used, as the package does not explicitly ask for any collaboration between learners.

**Curriculum requirement 6: Learning should be learner-centred**

According to McCombs and Whisler (1997) learner-centred classes require teachers to make provision for differences between learners. Differences could be in factors like learning styles, languages and cultural backgrounds of learners. Learning can also be made learner-centred by offering learners an element of choice in what they learn (McCombs & Whisler, 1997). In my Curriculum Requirements Checklist I looked at three ways in which learning could be made learner-centred (see Table 24).

The summary in Table 24 shows that the software makes provision for different learning styles only because it has pictures and text. This is common practice in computer software and does not suggest a conscious effort on the part of the designers to make provision for learning styles. Certainly no other mechanisms which could be accommodated using computers were utilised.

<table>
<thead>
<tr>
<th>Method of making learning learner-centred</th>
<th>Evaluator's comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The software makes provision for differences between learners (e.g. different learning styles or backgrounds).</td>
<td>The software makes provision for visual learning styles (by using pictures, maps and flow diagrams) and verbal learning styles (through the read-and-record activities and the use of data presented as text). Given the biological nature of the content, there is not much potential for the software to cater for other learning styles (e.g. aural or mathematical).</td>
</tr>
<tr>
<td>The software allows learners to choose what they are going to learn.</td>
<td>In the software learners can choose what software content they are going to cover and which activities to complete.</td>
</tr>
<tr>
<td>The software allows learners to choose how they are going to learn.</td>
<td>This was interpreted as learners being able to choose the sequence in which they will cover the content in the software. Learners can choose to follow any sequence through the content. They can choose whether to access sub-screens or to access the additional information provided in the software (e.g. using the Curiosity icons, to be discussed later, see Figure 31, page 138).</td>
</tr>
</tbody>
</table>

\(^8\) See Appendix V for typology of activities that can be carried out on computer (adapted from Mashalaba & Sanders, 2003).
Learning can also be regarded as learner-centred when learners are able to choose what they are going to learn, because they can base their choice on their prior knowledge or their interests. In the software learners can choose what software content they are going to cover and which activities to complete, by leaving out, without penalty, certain aspects. They can also choose the sequence in which they cover the software content. However, this is not the sort of choice referred to when we talk about accommodating learner choices. As with learning from a textbook, it is assumed that learners will cover everything in a computer-based software programme. No meaningful (real) choices are offered in the software.

Curriculum requirement 7: Continuous assessment should be applied

The new South African curriculum requires that on-going assessment should be applied throughout the year to provide learners with feedback on their progress towards achieving the required outcomes (Department of Education, 1997).

The assessment activities in the five topics are described and analysed in Appendix AG.

According to Sanders and Kasalu (2004, p. 920) one of the purposes of assessment is that it can be used to check "whether the intended outcomes have been achieved". No outcomes were explicitly stated in any of the five topics, but an analysis of the assessment activities showed they revolved mainly around the recall of knowledge (see Appendix AG). The lack of stated outcomes suggests that the designers had not considering any outcomes in their planning. Even if the designers had considered outcomes, they do not appear to have gone beyond planning for learners to use recall (and maybe comprehension of their knowledge).

Two of the three assessment standards for Learning Outcome 2 were judged to have been met in the five topics, but at a very superficial level. The accessing of knowledge used in the software revolves around the memorisation and recall of information that learners already have, which means that learners will not be constructing new knowledge.

The activities in the five topics fall into the category of text-based activities according to the typology of activities of Mashalaba and Sanders (2003), slightly adapted for use in this study (see Appendix V). There was some variation in the subcategories of text-based activities used in the software. Three different sub-categories of tasks were used (analysis, completion and review), but the three types used are simpler than the two types which were not used (translation activities – which involve the translation of data in form to another form and mind experiments – like supplying hypotheses and designing experiments). The three types of tasks used, which included fill-in-the-blank and supply-the-term tasks, mainly use the lower-order cognitive abilities given by Bloom in his taxonomy of cognitive objectives (see Bloom et al., 1956). The tasks mainly required knowledge and the comprehension of knowledge. The only opportunities for learners to apply their knowledge involved learners using their knowledge to answer questions they may not have come across before. Although this meets the requirement for application of knowledge (which means that learners apply their knowledge in new situations), it does so in a simplistic way. There are no opportunities to use the highest level of
cognitive abilities as listed in Blooms’ taxonomy, namely the skills of analysis, synthesis and evaluation (Bloom et al., 1956).

Sanders and Kasalu (2004) highlight the use of continuous assessment as a strategy to promote learning through making learners aware of the criteria they need to meet and by providing learners with meaningful feedback on their progress. The software offers learners two types of feedback on the assessment activities, both of which are of limited use to learners in monitoring their progress:

- **Feedback for individual assessment activities.** Learners can access scores for their performance in an activity by clicking on a tick in the bottom right-hand corner of the activity (see Figure 42). This icon opens an overlay entitled activity report. There is no label or mouse-over label for the tick, however, so the learner has to learn about the availability of this facility by trial-and-error.

![Figure 42. Example of an activity report overlay for an assessment activity](image)

Clicking on the blue tick in the bottom right-hand corner of the activity screen calls up the activity report overlay. The activity report shows the numbers of correct and incorrect answers and the result (as a percentage) for the activity.

Learners can click on
- the reset button to reset the activity.
- show errors, which causes red crosses to appear over any incorrect answers.
- show answers to see the correct answers.
- OK to accept the result for the activity feedback.

The reset feature in the activity report suggests that the activities can be used as drill-and-practice tasks, to be repeated until the learner gets a score of 100%. One potential benefit of feedback (allowing learners to monitor their progress so they know what they still have to learn) is not utilised by the designers. The information for each learner is not saved by the software, so learners are not able to track their progress. Where activities consist of a single question, the score in the activity report is given as 100% correct or 100% wrong. If learners have a wrong answer, this feedback cannot promote learning, because the absence of an explanation means that learners will not know why their answer was wrong.

- **Feedback for all the assessment activities in a topic.** Each topic has a screen called Check what you know (see Figure 43 for an example).
In the case of Topic 3 the screen opens as an overlay to the first screen (as shown in Figure 43), while for the other four topics it opens as a separate main screen. The screen lists the percentage of correct results for all the assessments in that topic, and also gives the learner an average for the assessments as a “lesson result”. Naming this screen the Check what you know screen is somewhat of a misnomer as there is no actual opportunity on this screen for the learner to check what they know and don’t know. They are merely given scores for the individual assessment activities.

If the software collected data on individual learner’s performance in the assessment activities, teachers would be able to analyse and monitor learners’ progress and to give learners feedback on what the learners know and what they still need to improve on. The package, however, does not offer teachers a database for recording each learner’s progress or a summary overview of the entire group’s performance. Teachers are unable to print the information for each learner, because the information is not readily printable (the screen has to be copied and saved in another document for printing). The only way teachers would be able to access the software data for learners would involve a tedious process of checking the Check what you know screen (see Figure 43) for each learner on each individual computer before learners logged off, and laboriously recording the marks for each topic by hand on a spreadsheet. This would provide the teacher with a snapshot of a learner’s marks for that topic, but they would not be able to determine what the learner’s strengths and weaknesses are, making it difficult for teachers to take appropriate remedial action.

Table 25 is a summary of which of the seven requirements of the new South African curriculum evaluated in the software package have been met. It shows that only one of the seven curriculum requirements – the curriculum content should be relevant to learners – has been met in the software. For certain other outcomes some attainment of these outcomes was achieved, but only at an extremely superficial level.
Table 25. Summary of the extent to which the seven curriculum requirements were met in the software

<table>
<thead>
<tr>
<th>Curriculum requirement</th>
<th>Extent to which the requirement was met in software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education should be outcomes-based</td>
<td>• No outcomes have been stated in the software.</td>
</tr>
<tr>
<td></td>
<td>• Two of three learning outcomes have been targeted, but at a superficial level.</td>
</tr>
<tr>
<td>Lessons should be activity-based</td>
<td>Neither of the types of activities used in the five topics can be said to promote activity-based learning.</td>
</tr>
<tr>
<td>Learning should focus on skills development</td>
<td>• No skills are taught in the software.</td>
</tr>
<tr>
<td></td>
<td>• Only lower-order cognitive skills are used.</td>
</tr>
<tr>
<td>The curriculum content should be relevant to learners</td>
<td>Most of the software content is relevant to South African learners.</td>
</tr>
<tr>
<td>Group work should be promoted</td>
<td>No group activities were used.</td>
</tr>
<tr>
<td>Learning should be learner-centred</td>
<td>The software cannot be said to offer learner-centred learning.</td>
</tr>
<tr>
<td>Continuous assessment should be applied</td>
<td>The assessment tasks</td>
</tr>
<tr>
<td></td>
<td>• do not assess outcomes, as intended by the new South African curriculum, since no outcomes have been stated in the software</td>
</tr>
<tr>
<td></td>
<td>• use only lower-order cognitive skills</td>
</tr>
<tr>
<td></td>
<td>• offer feedback which is of limited use to teachers and pupils.</td>
</tr>
</tbody>
</table>

The software package cannot be said to promote the requirements of the new South African curriculum to the extent that the software would support South African teachers struggling to implement the new curriculum.

5.8.2 Appropriateness of the content coverage of the EduRom package

The content of the software package was evaluated according to two criteria, the suitability of the content for teaching biodiversity and the use of language and grammar (see Appendix W for the Content Coverage Checklist).

Criterion 1: Suitability of content

Despite the claim by the software developers that this package “provides the answer to the latest curriculum”, the software content for biodiversity was found not to follow a sequence based on the content given in the National Curriculum Statement for Life Sciences (see Table 19, page 156) or any other logical sequence based on any of the books I consulted (e.g. Roberts, Reiss, & Monger, 1993). Instead, biodiversity is covered in a disjointed fashion (as indicated by the non-consecutive section numbers in Figure 44) across three different units of content and in five different topics in the software.
Chapter 5: Evaluation of the *EduRom* multimedia software package

The content sequence appears illogical for the following reasons:

- **The threats to biodiversity are not dealt with as one unit.** An entire topic (132) is devoted to types of pollution, while other threats to biodiversity are dealt with in a separate topic (133) (see Figure 44).

- **Misplaced topics.** The unit on *Human influence on nature* contains a topic which seems not to fit into this unit. Topic 134 (*Reducing the risk of disease and death*) appears out of place in a unit headed *Human influence on nature*. This topic was not evaluated in this study, but it is worth noting its odd placement – slotted in between two topics dealing with threats to biodiversity and a topic dealing with conservation. Topic 134 actually has little to do with the effects of human activities on the environment – it deals with reducing the effects of polluting the environment on human health through recycling and certain methods of waste disposal. This content is difficult to link to the content in the topics which precede and follow Topic 134.

- **The five-kingdom classification system (covered in Topic 3) is dealt with before a definition of biodiversity is given and the levels of biodiversity are discussed (Topic 124)** (see Figure 44). In my opinion it would make more sense to first define biodiversity as referring to the variety of living organisms on Earth and then to outline the different levels of diversity (ecosystem, species and genetic) and establish the relationships between these levels before discussing why a system of classification is necessary and how this is done.

In a bid to counter the disjointed software coverage of the content on biodiversity, I will report the findings using the **order** of three content sections I devised for the knowledge area *Diversity, change and continuity* at Grade 10 level (see Table 20, page 156), which is based on the order of content stipulated in the National Curriculum Statement for *Life Sciences* (Department of Education, 2003).

The three content sections are

- biodiversity of plants and animals
• significance and value of biodiversity to ecosystem function and human survival; conservation of biodiversity
• threats to biodiversity

The quality of the software content for the different sections of work will be judged against the terms and concepts which should be covered in the section *Diversity, change and continuity* at Grade 10 level (see Appendix X).

<table>
<thead>
<tr>
<th>Biodiversity of plants and animals</th>
</tr>
</thead>
</table>

The content on biodiversity of animals and plants is limited to a single main screen in Topic 124 (see Figure 45 on the next page) which is sandwiched in between a discussion of the components of ecosystems and a discussion of the different types of biomes. Initially this content appeared out of place in a topic on ecosystems, but after some consideration I decided that the designers probably placed it here to fit in with the concept of ecosystem diversity as illustrated by the different biomes.

The software content on biodiversity of plants and animals is inadequate:

• The definition of biodiversity offered is wordy and unclear compared with the succinct definition “the great variety of living organisms” used by Bezuidenhout et al. (2005, p.120).
• No definition of ‘ecosystem diversity’ is offered.
• The references to ‘species diversity’ and ‘genetic diversity’ are vague.
• There is no attempt to explain the relationships between the different levels of biodiversity.

If the designers placed this content in the topic dealing with ecosystems in order to introduce different biomes (i.e. ecosystem biodiversity), it was inadequate for all the reasons discussed above.
The text describes diversity as the number of species in "an organized group of organisms or biocenosis". It is difficult to interpret what this statement means, since it is neither a correct description of species diversity nor of ecosystem diversity.

**Curiosity** (keyhole) icon which opens a new series of sub-screens to the Curiosity sub-screen.

Biological diversity is defined here as "the forms of existence of living matter, all creatures together with their unique features and adaptations or all genes constituting the record of the programme of life on Earth."

**Zoom in** icon which opens the picture in the circle on a new screen (sub-screen).

Figure 45. The screen with content on biodiversity of plants and animals in Topic 124

In Figure 45 information on the value of diversity is accessed by clicking on the **Curiosity** keyhole icon on the main screen (see on previous page). Figure 46 shows the sub-screen which opens when the **Curiosity** icon is clicked on. A series of sub-screens can then be opened from this sub-screen.

Clicking on one of four circles calls up one of four pictures in the circle, but without the audio accompaniment. Each of the pictures can be enlarged on a separate sub-screen by clicking on the **Zoom in** icon. The text message for these pictures is similar to the audio message.

Clicking on the **Play** icon starts an audio message that relates to the pictures in the circle. The four pictures change automatically until the audio ends.

The picture in the circle show various crops with the caption **Nature useful to people**. The first picture shows some cash crops (rye, rice, oats and wheat) to represent the economic use of biodiversity. The second and third pictures refer to the medicinal uses of products produced by various organisms (penicillin and a fungicide). The fourth picture shows a forest being cleared and makes reference to genes "which could carry important information for a product useful to humans" being destroyed when a species is wiped out.

**Figure 46. One of the sub-screens to a Curiosity screen which contains important information on the value of diversity**
The complicated system of sub-screens to the sub-screen shown in Figure 46 made the information on the value of diversity almost appear hidden. There are two problems with this complicated system. Firstly, users may miss the information on the value of biodiversity (which is essential for an overall understanding of the concept of biodiversity and the need for conservation) if they decide not to click on this icon. Secondly, I felt as if I had lost my way after accessing all the sub-screens from the Curiosity icon and had to re-establish that the topic was actually dealing with ecosystems.

The information on the value of diversity (see Figure 46) is useful, but was found to be incomplete. The software fails to explore the value of diversity to any appreciable extent because it does not touch on uses such as the importance of species diversity for the provision of food, fuel, shelter and building materials for humans or the recycling of gases and nutrients as carried out by ecosystems.

One of the developers, when questioned on one of his visits to the school about the disjointed nature of the content for biodiversity, answered as shown in the extract from my log in Figure 47. This was the first indication I had that the software had not (as claimed) been developed specifically for the new South African curriculum and that teachers wanting to use this software to teach biodiversity as part of our curriculum would have to spend time bookmarking the sections they wanted to include in lessons on ‘biodiversity’.

He looked at the screen or at a point to the left of the screen as he matter-of-factly explained that the software is based on the European, specifically the Polish, curriculum. I then pointed out that the brochure supplied by the suppliers claimed that the software is based on OBE principles and claims to cover the “majority” of the curriculum. Surely, if something is sold or marketed in SA, it would be safe to assume that the curriculum being referred to is the SA curriculum?

One of the science teachers (T3) also pointed out that there is no distinction between lessons for different grades, to which I added that the software doesn’t seem to be arranged in distinct lessons. Mr. C’s response was that teachers would have to bookmark information from different parts of the software to make up a lesson.

Mr C is one of the developers of the software package.

Another reference to biodiversity is found in Topic 3 – where it is clumsily referred to as “the diversity of living nature” (‘living organisms’ would have been a better term to use instead of ‘living nature’). This reference to biodiversity is used as an introduction to the need for a system of classification without offering any definition for the term biodiversity.

In summary, the software does not offer a clear and succinct definition of biodiversity, nor does it make clear that there are three levels of biodiversity and how they relate to each other.

The content on classification and the five-kingdom classification system was also covered in a less than satisfactory manner in the software. Classification is introduced under the heading “Unity or
diversity?" (see Figure 48) for the screen and sub-screens introducing the variety of life forms). The text refers to two features which 'unite' organisms, but the sentence is clumsily worded. The "common features of living organisms" is given as a common feature (see Figure 63), which is does not make sense. The other common feature of living organisms mentioned in the software is "their cell structure", but the cellular structure of organisms differs considerably and is used to differentiate between organisms. For example, the cell structure of some organisms includes membrane-bound organelles (eukaryotic) while other organisms do not have membrane-bound organelles (prokaryotic); organisms can have cell walls composed of cellulose (plants) or chitin (fungi) or peptidoglycan (bacteria), while the cells of other organisms do not have cell walls (animal cells). If the text message in the software meant to use the fact that all organisms are made up of cells as a unifying feature, then this was not communicated clearly.

The text reads "You have already learnt the common features of living organisms, as well as their cell structure. You can therefore see that the world of living organisms can be regarded with a certain unity, at least with regard to these two features."

This text reads "On the other hand, if you compare a paramecium with an elephant or a sequoia with a pineapple, you see how diversified living nature is. Man has always been fascinated by the diversity of the world of living organisms, and has tried to describe it, name and classify it. That is why this enormous domain has been divided into smaller groups.

The text on the sub-screen on the left-hand side reads "The world of living organisms is very diverse. What can a paramecium and an elephant have in common?"

Figure 48. The screen and its sub-screens introducing the variety of living forms
The ‘diversity’ in the heading refers to how different organisms are. This diversity of form is illustrated by comparing photographs of different organisms (see Figure 48). I thought one of the two comparisons was inappropriate because the graphics show a stylised diagram of the internal structure of the Paramecium compared to a photograph of the external appearance of an elephant. The set of photographs on the right-hand side (see Figure 48) allow a better comparison because they are both photographs which show the external appearance of the two different plants.

The need for classification is dealt with superficially. The software gives mans’ ‘fascination’ with the “diversity of the world of living organisms”, as the reason why people “describe it, name and classify it” (see Figure 48). Roberts et al. (1993, p. 92) describe the need for classification as a pragmatic method humans use to create “order out of chaos” when faced with the vast variety of living organisms on Earth. This is a more useful description of the need for classification than the one offered in the software. The text on the sub-screen comparing the paramecium and the elephant (see Figure 61) poses a question about what these two organisms could have in common. Answering this question does not help users to understand the need for classification.

- An attempt to show the different levels of taxonomy using the graphic of the Russian nesting doll graphic was judged to be ineffective because, as previously discussed, the graphic does not accurately represent the relationships between the different taxonomic levels (see Russian nesting doll graphic, on page 166, Figure 41).

- The problems with the software coverage of the five-kingdom classification system centre on the fact that the features used to classify the organisms in a taxon are not distinguishing characteristics of the taxon or are not the features usually spelled out by biologists. Figure 49 (on the next page) shows the screen introducing the Monera and Protista and one of its sub-screens. Figure 50 (see page 179) shows the screen introducing the plant kingdom and one of its sub-screens. These figures will be used as examples to highlight the problems with the features used in the software package to classify organisms.

- The features given in the software as distinguishing features of the kingdom in question are often incomplete when compared to the features given in the reference books I consulted (Jones & Jones, 1997; Roberts et al., 1993). The main screen introducing the Monera and the Protista (see Figure 49) does not use terms that should be covered when teaching the distinguishing features of these kingdoms. The Monera are described as “microscopic, single-celled organisms” lacking “a distinctive cell nucleus” and the Protista are said to be “single-celled” and to have “a clearly distinguishable cell nucleus”. These descriptions fail to make it clear that the presence or absence of any membrane-bound organelles (and not only the presence or absence of a true nucleus) is also an important distinguishing feature to separate the Monera from the Protista. These descriptions also neglect to use the terms ‘eukaryotic’ and ‘prokaryotic’ in relation to the presence or absence of membrane-bound nuclei and other membrane-bound organelles. It is important that learners understand these terms because they are widely used in biological literature.
The numerous photographs used to show examples of the organisms in the different taxonomic groups are not labelled, so they do little to illustrate the distinguishing features used to group organisms. The text on the sub-screens also fails to emphasise the features which allow that organism to be placed in a particular taxonomic group. For example, the caption for the photograph on the sub-screen shown in Figure 49 – “Streptococcus pyogenes bacteria seen through a microscope” – implies that bacteria are microscopic but does not emphasise any of the structural features which make bacteria ‘prokaryotic’. The description also does not make it clear that these are chains of individual bacterial cells. The unicellular nature of bacterial cells is therefore not made clear.

The top half of this screen introduces the Monera, while the bottom half of screen introduces the Protista.

Clicking on pictures in the circles on the main screen opens a larger version of that picture on a sub-screen.

One of the sub-screens, which has a picture of bacteria, is shown on the left. The caption for the photograph on the sub-screen reads “Streptococcus pyogenes bacteria seen through a microscope.”  

Figure 49. The screen introducing the Monera and Protista kingdoms and one of its five sub-screens

- The numerous photographs used to show examples of the organisms in the different taxonomic groups are not labelled, so they do little to illustrate the distinguishing features used to group organisms. The text on the sub-screens also fails to emphasise the features which allow that organism to be placed in a particular taxonomic group. For example, the caption for the photograph on the sub-screen shown in Figure 49 – “Streptococcus pyogenes bacteria seen through a microscope” – implies that bacteria are microscopic but does not emphasise any of the structural features which make bacteria ‘prokaryotic’. The description also does not make it clear that these are chains of individual bacterial cells. The unicellular nature of bacterial cells is therefore not made clear. The screen introducing the plant kingdom (see Figure 50, page 179) has twenty-five sub-screens which show photographs of plants, used to illustrate the different plant phyla and classes of angiosperms. There is no attempt, however, to emphasise the differences between these groups or to explain the terms used in the descriptions of these examples. For example, the caption to the sub-screen shown on the right in Figure 50 reads “Beeches are dicotyledonous angiospermous plants”, which sheds no light on what makes the beech dicotyledonous or angiospermy.
Terms that should be used to describe the characteristic features of the different groups (and which should be included to comprehensively teach this section of work) are either omitted (see ‘prokaryotic’ and ‘eukaryotic’ in Figure 49, on page 178) or are not explained. The main screen introducing the plant kingdom (see Figure 50, above) uses a number of terms which are not explained:

- *autotrophic* is used without being explained so that the distinction between autotrophic and heterotrophic organisms is not explicit. The term *heterotrophic* is similarly used in the introduction to fungi without being explained.
- *gymnospermous* and *angiospermous*.
- *monocotyledon* and *dicotyledon*.

It is possible that learners could work through this topic and not fully understand what classification is, why it is done or how it is done. The large number of photographs is useful in illustrating the diversity.
of organisms, but without this having been clearly linked to the concept of biodiversity, learners may fail to fully appreciate the significance of the variety of organisms shown in the photographs.

| Significance and value of biodiversity to ecosystem function and human survival; the conservation of biodiversity |

This section of content is spelled out in the National Curriculum Statement (see Table 19 on page 156) and included in the Content Coverage Checklist (see Appendix W, criterion 1, row 2), but was poorly addressed in the software:

- The term *conservation* is not used in any of the explanations. The closest the software comes to offering a definition for conservation is found on the screen shown in Figure 51 (on the next page). On this screen the phrase ‘protecting nature’ is used when referring to conservation. There is an audio message in response to the question “Why should nature be protected” (see Figure 51), which comes across as trite. The reference to not hurting any living “being” excludes organisms other than humans and may not be what the developers were trying to get across. The whole message lacks conviction and does not convey the sense of urgency with which we should be approaching the issue of conservation of biodiversity at this point in human history.

- The content on the ‘need for conservation’ continues on a screen headed “We need all of nature” (see Figure 52, on the next page), but the content does little to foster an understanding of the need for conservation. Instead of relating the need for conservation to the negative impact human activities have on the environment, the text on this screen emphasises the need to keep “our living environment safe for us and reasonably cheap to use”. It states that “nature does not need to be directed, controlled or told what to do [because] it has been looking after itself for millions of years”. It goes on to discuss how we could breed “all plant species in computer-controlled laboratories” but that this would be costly and nature does it “all by itself if only it is allowed to”. The viewpoint that we can produce virtually everything we need from plants under laboratory conditions is simplistic and unrealistic, and completely ignores the delicate balance which exists between the biotic and abiotic factors of the world’s ecosystems and the dramatic negative influence of humans on biodiversity. The audio message on this screen (see Figure 52) is one of many instances in the software package where a potentially valuable message may be obfuscated by clumsy wording. The wording used in the audio segment makes it sound as if the environment is an entity on its own, separate from human existence, which needs to be kept “alive as a whole”. The message undermines the interconnectedness between humans and the environment.
In response to the question "Why should nature be protected" above the photograph, the audio message (accessed when clicking on the "Play" icon) is "People want to protect nature because flowers and butterflies are nice, birds sing beautifully, because it's good to relax in nature, because we should not hurt any living being, because we ought to leave to future generations what we have had. All these reasons are important, but they may not convince everybody. Not all people like flowers or animals or care about other people, let alone animals or plants. But one reason should be obvious to everybody: nature is indispensable for our existence – all of nature."

**Figure 51. One of the screens on which the need for conservation is discussed**

The audio message on the screen is that "In order to keep using natural resources in the future we must keep the environment alive as a whole, because we do not know which of its elements may turn out to be of vital importance for its existence".

There are four sub-screens to this screen. Each sub-screen shows an example of an organism with text which discusses the value of the organism.

**Figure 52. The screen which deals with the need for conservation and the value of biodiversity (on four sub-screens)**
• The ‘value of biodiversity’ is not clearly conveyed in the software. The content relating to the ‘value of biodiversity’ is found on four sub-screens to the screen shown in Figure 52 (on previous page). Similar content on the value of biodiversity was previously depicted in Topic 124 on a series of sub-screens accessed by means of a Curiosity icon. This is a method commonly used in the software to access lots of information via one (main) screen, but, since it is optional whether or not access the sub-screens, learners who do not access them may miss out on valuable information. Two of the sub-screens with content on the value of biodiversity are shown in Figure 53.

There are two problems with the content on the value of biodiversity in the software:

- **The value of the organism is not fully described.** The sub-screen on the top in Figure 53 shows phytoplankton. Although correctly described as having enormous biological importance because of their roles as ‘producers of organic matter and oxygen’, the software does not fully explain the role of phytoplankton in reducing atmospheric carbon dioxide levels and combating climate change. This is but one example of information in the software that is either not fully explained or not clearly linked to other concepts.

- **It is not clear what the value of the organism is.** The sub-screen at the bottom in Figure 53 shows the Colorado potato beetle which is described as a pest without any discussion of the role of the organism in the ecosystems in which it occurs, so it is not clear why it this organism was included in a series of sub-screens depicting the value of biodiversity.
Threats to biodiversity

Besides the disjointed coverage of the content related to threats to biodiversity (discussed at the top of the previous page), the content coverage for dealing with content spelled out in the National Curriculum Statement for this section (see the Content Coverage Checklist – Appendix W, criterion 1, row 3) is incomplete:

- No explanation is offered for what is meant by ‘loss of biodiversity’.

- Only four main threats to biodiversity are covered: pollution (a whole topic is devoted to discussing different types of pollution), invasive species, habitat loss and “direct killing” (which covers hunting, poaching and commercial fishing). There is no mention of climate change or farming methods like monoculture as threats to biodiversity. There is also little effort in the software coverage to link together (as threats to biodiversity) the information on pollution in Topic 132 and the other threats covered in Topic 133. The topic on pollution does not make it clear that pollution threatens biodiversity by contributing to habitat loss. No mention is made of destroying food chains (e.g. through oil spills or the use of insecticides) or any other factor which could destroy habitats. There is a brief reference to DDT in which it is incorrectly referred to as a new substance created by man that “cannot be utilized by nature” (which I interpreted as ‘cannot be biodegraded’). No mention is made of the toxic effects of DDT in food chains. Strangely, the content on pollution focuses on heat, noise and “transgenic organisms” as the major “factor groups” (which I understood as the major types) of pollution, while carbon dioxide and sulphur dioxide are referred to as “other types” of pollutants and dealt with superficially in a table. The table contains a number of examples of clumsy wording which may confuse learners (e.g. “mainly all the combustion of fossil fuels” as the source of sulphur oxides and “dying of plants due to damage” as the effect of nitrogen oxide on other organisms). Both nitrogen and sulphur oxide refer to any one of a group of oxides of these elements, yet the table refers to sulphur oxide, but nitrogen oxide. This table contains the only reference to acid rain and global change in the five topics evaluated. Sulphur oxide is described as contributing to acid rain, while it is not clear from the table that nitrogen oxide does the same.

- There is no discussion of the ‘consequences of the loss of biodiversity’ (required by the National Curriculum Statement for Life Sciences). The software focuses on species going extinct without regard for the broader implications of the loss of species. There is a series of three screens which deal with the causes of extinction due to invasive species, habitat loss and “direct killing” respectively. The lack of headings which indicate the focus for this series of screens makes it difficult for users to discern that the screens are dealing with the causes of extinction. For example, the heading on the first screen reads “Sudden species extinctions”, which does not suggest that causes of sudden species extinctions will be discussed. This heading also fails to suggest that this screen deals with loss of habitat as the first of three causes for the loss of biodiversity. The learner would have to infer from the audio insert (which attributes the decline in the number of species to the destruction of habitats caused by human economic activity) that this screen deals with the effects of habitat loss.

- Also, terms that should be used in relation to this content are not used. The software does not use the terms indigenous and exotic in relation to the content on alien plants, nor does it use
the more common term competition instead of the non-biological term “rivalry”. The heading to the second of the three screens is misleading because it talks about the “rivalry and predation of alien species”, which makes it sound as if the alien species are being preyed upon.

**Criterion 2: Language and terminology usage**

The grammar usage in the software package (see second part of Content Coverage Checklist included as Appendix W) reveals a number of problems:

- There are a number of grammatical and spelling errors in the software (using U.K. English) as shown in Table 26 below. The spelling error “bioime” in Topic 124 is significant because the misspelled word is given as the answer to an assessment question.

<table>
<thead>
<tr>
<th>Topic and screen</th>
<th>Poor Punctuation</th>
<th>Spelling errors</th>
<th>Missing space</th>
<th>Incorrect comma use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topic 3 – screen 12</td>
<td>“best-known”</td>
<td>“bioime”</td>
<td>“humans or animal intestine”</td>
<td>“evento”</td>
</tr>
<tr>
<td>Topic 3 – sub-screen of screen 15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 124 – screen 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 133 – screen 2</td>
<td>“characterized” (US spelling)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 135 – screen 3</td>
<td>“environmnet”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topic 124 – screen 7</td>
<td>“many, variants and … “</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- A number of examples of poor language usage have already been pointed out in the previous section on content coverage. Other instances where the language used to convey content is not clear and would be difficult for even an English first-language user to understand are shown in Appendix AH.

- The software does not always use subject-related terminology at an appropriate level for Grade 10 learners. There are a number of instances where terms are used that Grade 10s are unlikely to be familiar with, without any explanation of these terms. Examples of such terms include “haemoglobin”, “oviparous”, “viviparous” and “cartilaginous”.

### 5.8.3 The use of appropriate pedagogical strategies to enhance learning

The completed Pedagogical Strategies Checklist is shown in Appendix Al. Only one of the strategies to promote learning identified from the literature and included in the checklist was judged to have been used effectively in the software package. The strategy that was used effectively in the software involves the presenting of information to be learnt in small chunks. According to Miller (1956) working memory can only handle between five and nine elements of information at a particular time. Presenting information in small chunks promotes learning by preventing overloading of working
memory. The software typically presents information in two or three separate ‘chunks’ on a screen (see Figures 51 and 52, page 181) for examples of how screen content is arranged in small ‘chunks’ of information). Each chunk typically consists of only a few sentences. The ‘chunks’ of information are physically separate from each other on screen, facilitating the processing of one chunk by users before they move on to the next chunk.

A number of strategies to promote learning identified from the literature were not used at all in the software:

- The software does not state any goals for learners to achieve. Having clear goals stated for their learning gives learners a clearer idea of the purpose of the learning (Angelo, 1993).

- The software does not include any tasks which are situated within a meaningful, real-life context. According to Vygotsky’s Social Development Theory (1978) and the Theory of Situated Learning (Lave & Wenger, 1991), learning is more likely to occur within the context of experiences and contexts that are relevant to the learner. However, not all topics lend themselves to being situated like this. One way in which the software could have situated some biodiversity-related tasks within real-life contexts is to have used case studies. For example, the value of biodiversity and the impact of humans on the environment could have been illustrated by means of a case study involving a local ecosystem (for example, a wetland) being threatened by a construction development and the effects of the loss of that ecosystem for the organisms found there and the effects on human who may use resources (like reeds) from the ecosystem. A real-life context like this would make it easier for South African learners to identify with the concepts being taught.

- The software does not include tasks which can be carried out co-operatively. Collaboration between individuals has been shown to promote learning. According to Vygotsky’s Social Development Theory (1978) social interactions allow learners to attach meaning to knowledge and skills making it more likely they will develop an understanding of what they have learned. The onus to use collaboration as a pedagogical strategy to enhance learning would thus fall on teachers. Teachers would have to organise that learners work in groups on tasks arising from the software content or based on the software content.

- The software does not make provision for the application of skills in new contexts. Angelo (1993) believes that learning to transfer skills to new contexts requires a great deal of practice. The software fails to promote the development of learners’ skills.

The remaining strategies were evaluated in the checklist as having been used ineffectively in the software. Three of the strategies form part of assessment as a broader learning principle, and will be considered together.

- The software does not make effective use of active engagement to promote learning. The limited number and types of activities used in the software are unlikely to lead to learners constructing knowledge.

- The software does not require learners to use a variety of levels of cognitive activity. The tasks and activities require only lower-order cognitive levels, according to Bloom’s taxonomy. The software could have required learners to use higher-order cognitive levels by including tasks
which required learners to use dichotomous keys to identify organisms in Topic 3 (*How has man classified the world around him?*). Using dichotomous keys requires learners to analyse and synthesise information, both of which are higher-order cognitive levels according to Bloom’s taxonomy.

- The software does not represent knowledge in alternative ways. According to Gardner’s theory of multiple intelligences (1983), teaching and learning should make allowances for the fact that different individuals possess different forms of intelligences in varying degrees. The use of just pictures and text in the software does not cater for all different forms of intelligence.

- The software does not make effective use of audio and video, and animation, towards creating a motivational learning environment. The only feature that contributed effectively towards creating a motivational environment is the use of numerous colour photographs in the software, which plays a significant role in gaining users’ interest and attention.

- The software fails to use assessment effectively to promote learning. The software package offers regular assessments because of the assessment tasks at the end of each topic. However, it is not sufficient to have regular assessments. According to Angelo (1993) learners require regular feedback on their progress. Regular feedback on their performance allows learners to know what they can do and what they still need to improve on (as discussed in Appendix Q which deals with principles of good teaching practice). The feedback offered to learners in the software was judged to be ineffective because it was not useful to learners. Another aspect of assessment is that there should be assessment tasks with more than yes/no or right/wrong answers. The software only made use of assessment tasks with right/wrong answers. Overall, assessment as a learning strategy was used ineffectively in the software.

This section aimed to answer the research question relating to how well the software package could support teachers to effectively teach the new section of work on biodiversity in the new South African school curriculum.

Neither of the two components of pedagogical design evaluated in this chapter was adequately supported in the software package.

- The content coverage for biodiversity was found to be illogical and incompatible with the sequence of content given in the National Curriculum Statement for *Life Sciences*. The content coverage was judged to be incomplete because the software content failed to offer definitions and did not include terms that need to be included to comprehensively teach this section of work. There were a number of problems relating to grammar usage in the software package and the subject-related terminology used was not at an appropriate level for Grade 10 learners. This poor coverage and lack of alignment was reason why the teacher who had started using the programme eventually dropped it, (see Chapter 4, page 104) in spite of the large financial investment in obtaining the licence software.

- Only one of the twelve pedagogical strategies to enhance learning (as identified from the literature) was used effectively in the software.
Based on the inadequate pedagogical design of the software package, it would not offer effective support to South African teachers teaching biodiversity as part of the new school curriculum.

5.8.4 The interface design of the software package

The Interface Design Checklist (see Appendix Z) was used to evaluate two categories of design elements of the Edurom interface, the navigational devices used and the integration of multiple media (text, images, animation, audio and video).

### Navigational features

**Use of icons**

A review of the literature suggested two main guidelines for the use of navigational icons. Firstly, navigational icons should help users to move around in the package in an intentional manner with the minimum of difficulty so as not to “distract learners from the task at hand” (Oliver & Herrington, 1995, p. 7). Secondly, navigational icons should be used in a consistent manner to reduce difficulties with navigation (Oliver & Herrington, 1995). Brooks (1993, cited by Oliver & Herrington, 1995) advocates simple and consistent screen designs. The large number of icons used in the software evaluated in my study (65) suggests that the screen design is not simple. I identified the following problems with the sixty-five icons used in the five software topics I evaluated:

- **The use of graphic icons without text.** Amory and Mars (1994) and Sanders and Ayayee (1997) found that South African users are more likely to understand buttons containing explanatory text than buttons without such text. None of the sixty-five icons used in the five software topics have explanatory text. The icons in the software do, however, have mouse-over labels which, although not as effective as icons with explanatory text, are the next best option. Mouse-over labels are not as easy to use as control buttons with explanatory text because one has to move the mouse over the icon to find out what it means.

- **The use of icons that do not have mouse-over labels.** Twenty-two of the 65 buttons (34%) do not have mouse-over labels (see Table 27 for a summary of the icons that do not have mouse-over labels). This means that users have to find out what the icon means by trial-and-error, which could frustrate users. One of the icons shown in the table (see the icon numbered 18) does not have a mouse-over label and does not lead to an action (the listen, read and record activity in Topic 3, where this icon is used, does not work). I inferred the possible meaning of this icon from icons used in similar types of activities in the other four topics which I evaluated.
Table 27. Summary of 22 icons in the five topics that do not have mouse-over labels.

<table>
<thead>
<tr>
<th>Number</th>
<th>Icon</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1" alt="Icon 1" /></td>
<td>Go to the main contents page (from the first screen of a topic) or go to the contents page for that topic from a screen within a topic.</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2" alt="Icon 2" /></td>
<td>The tick appears once users start recording a fact, but does not lead to an action.</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3" alt="Icon 3" /></td>
<td>The numbers correspond to the number of activities for topics 124, 132, 133 and 135. A tick appears over the circle above the activity number when that activity has been correctly completed.</td>
</tr>
<tr>
<td>4</td>
<td><img src="image4" alt="Icon 4" /></td>
<td>Denotes that there is more than one screen with different content under the same heading.</td>
</tr>
<tr>
<td>5</td>
<td><img src="image5" alt="Icon 5" /></td>
<td>Clicking on the icon changes the picture on the screen.</td>
</tr>
<tr>
<td>6</td>
<td><img src="image6" alt="Icon 6" /></td>
<td>Restore an image to its normal size after zooming in.</td>
</tr>
<tr>
<td>7</td>
<td><img src="image7" alt="Icon 7" /></td>
<td>Clicking on the yellow circles either changes the picture in a circle or starts a different audio message for each circle.</td>
</tr>
<tr>
<td>8</td>
<td><img src="image8" alt="Icon 8" /></td>
<td>Clicking on a number changes the picture on screen. Accompanies a picture on screen which suggests that there are other pictures.</td>
</tr>
<tr>
<td>9</td>
<td><img src="image9" alt="Icon 9" /></td>
<td>Opens the activity report overlay for a particular assessment task.</td>
</tr>
<tr>
<td>10</td>
<td><img src="image10" alt="Icon 10" /></td>
<td>Opens the gallery of species at a photograph of the named organism.</td>
</tr>
<tr>
<td>11</td>
<td><img src="image11" alt="Icon 11" /></td>
<td>Numbers represent different assessment activities for that topic.</td>
</tr>
<tr>
<td>12</td>
<td><img src="image12" alt="Icon 12" /></td>
<td>Opens an enlarged version of the picture on a sub-screen.</td>
</tr>
<tr>
<td>13</td>
<td><img src="image13" alt="Icon 13" /></td>
<td>Resets the activity.</td>
</tr>
<tr>
<td>14</td>
<td><img src="image14" alt="Icon 14" /></td>
<td>Numbers represent different screens which have the same type of activities on them.</td>
</tr>
<tr>
<td>15</td>
<td><img src="image15" alt="Icon 15" /></td>
<td>Plays the audio insert.</td>
</tr>
<tr>
<td>16</td>
<td><img src="image16" alt="Icon 16" /></td>
<td>Pauses the audio insert.</td>
</tr>
<tr>
<td>17</td>
<td><img src="image17" alt="Icon 17" /></td>
<td>Stops the audio insert.</td>
</tr>
<tr>
<td>18</td>
<td><img src="image18" alt="Icon 18" /></td>
<td>Meaning of icon not clear since icon not labelled and the activity does not work. Function may be for users to repeat and record a fact (which will have disappeared from the screen).</td>
</tr>
<tr>
<td>19</td>
<td><img src="image19" alt="Icon 19" /></td>
<td>Opens an overlay with extra information on the organism/topic with which the icon is labelled.</td>
</tr>
<tr>
<td>20</td>
<td><img src="image20" alt="Icon 20" /></td>
<td>Go back to the screen which introduces the 5-kingdom classification system.</td>
</tr>
<tr>
<td>21</td>
<td><img src="image21" alt="Icon 21" /></td>
<td>Starts an audio insert which reads out the fact next to this icon.</td>
</tr>
<tr>
<td>22</td>
<td><img src="image22" alt="Icon 22" /></td>
<td>Function of this icon not clear.</td>
</tr>
</tbody>
</table>

* The icons which do not have mouse-over labels have been numbered to make it easier to refer to them in my discussion.
• **The use of non-intuitive symbols for icons.** The use of intuitive symbols would make it easier for users to discern the meaning of control buttons. Oliver and Herrington (1995, p. 8) suggest that the control buttons “should be intuitive rather than clever in their design”. Forty-seven of the 65 symbols (72%) used in the software are not intuitive. Where non-intuitive symbols are used, users would find it difficult to work out what purpose those icons serve. Some examples of icons for which non-intuitive symbols are used are

- Icon 13 in Table 27. It is difficult to describe what this icon looks like, let alone to work out what it means. The symbol looks like a green puzzle with a piece of the puzzle that needs to be fitted. The icon does not have a mouse-over label, which makes it even more difficult for users to understand its meaning.

- Icon 19 in Table 27. The symbol for this icon is a yellow magnifying glass with the name of the topic alongside it for which additional information is available. Using a magnifying glass to show users that they can access additional information on a topic is problematic because a magnifying glass is usually associated with enlarging an object, not obtaining information. A possible interpretation of the magnifying glass as a symbol is that magnifying glasses allow more detail of an object to seen, but this is not what the icon means. The icon also does not have a mouse-over label, which makes it even more difficult for users to understand its meaning.

- Icon 21 in Table 27. The symbol shows an object which could be a torch emitting light rays (which was my first impression) or a speaker emitting sound. Clicking on the icon plays an audio insert, so a ‘start’ button (which is used elsewhere in the package for the same function of playing an audio insert) would have been more effective. The icon does not have a mouse-over label, which makes it even more difficult for users to work out its meaning.

- Icon 22 in Table 27. The symbol shows the number ‘100’ in red within a green circle. The symbol resembles a ‘shooting target’. This icon is only found on one screen in the five topics and it is not clear what its purpose is. The icon does not have a mouse-over label nor does it lead to an action.

• **Icons that are visible only when the mouse is moved over them.** Two of the 65 icons used in the package only become visible when the mouse is moved over them. The two icons can be used to move up or down a main screen, but are not readily visible on screen. I only discovered these arrows by accident – after having used the package a number of times – when I moved the mouse over the area in which one of the arrows can be found.

• **Different cues lead to the same action.** Thirteen pairs of icons used in the five topics lead to the same action (see Table 28, on the next page). Ten of these icons with the same action as other icons are found in Topic 3. These ten Topic 3 icons have a different layout to the equivalent icons in the other four topics which were evaluated, creating two distinct sets of icons. I am not sure whether the software topics that were not evaluated use the icon set from Topic 3 or the set from the other four topics, as further investigating this inconsistency was not directly relevant to this study. I found the use of different cues for the same action confusing.
Chapter 5: Evaluation of the *EduRom* multimedia software package

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**Table 28. Icons which have the same action in the package**

<table>
<thead>
<tr>
<th>Icons</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Go to the main contents page (from the first screen of a topic)</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Go to the “read, listen and record” activity for a topic.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Go to the “Check what you know” screen for a topic</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Start playing an audio insert.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Stop playing an audio insert.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Record.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Change the picture in a circle on the screen.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Open the gallery of species to the named organism. The organism’s name appears in the mouse-over label for the icon in the first column.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Opens an overlay with additional information on a topic. This could be a single overly or a series of individual sub-screens.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Numbers represent different assessment activities for a topic.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Open an enlarged version of the picture on a sub-screen.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Start an audio insert which reads out the fact next to the icon.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>Open the gallery of photographs used in the package, although the icon in the first column opens the gallery at a particular image (the image on the sub-screen on which the icon is found).</td>
</tr>
</tbody>
</table>

**The use of buttons in the package that do not lead to an action.** Two of the 65 icons used in the software do not work at all. These icons and their meanings are shown in Table 29.

**Table 29. Icons used in the software that do not lead to an action**

<table>
<thead>
<tr>
<th>Icon</th>
<th>Name</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>No label</td>
<td>The tick appears once users start recording the fact, but does not lead to an action.</td>
</tr>
<tr>
<td><img src="image" alt="Icon" /></td>
<td>No label</td>
<td>Not clear, as the icon does not lead to an action.</td>
</tr>
</tbody>
</table>

---

The use of icons in the software is not conducive to users navigating the package with the minimum of difficulty. The problems users are likely to encounter when using the icons in the software leads to a great deal of frustration and could lead to them abandoning the software. Alternatively it could
negatively impact on their learning. Some of the limited space in users’ working memory would be taken up with attending to the problems with the icons and reduce the amount of memory available to process of the screen content, thereby reducing learning.

**Mapping**

As previously stated, ‘mapping’ refers to the package’s “ability to track and graphically represent to the user his or her path through the program” (Reeves and Harmon, 1997, p. 490). The basic principle for mapping is that users need to know where they currently are in a package, what is available in a package, how to get to where they want to go, and where they have been (Sanders & Fletcher, 2003). Figure 54 shows a portion of a main screen from the software, where users would find the information they would use to orientate themselves in the package. The explanations for the screen elements shown in Figure 54 have been numbered in a clockwise fashion (starting from the top) for ease of reference in the discussion after the figure.

![Figure 54. A section of a main screen showing the information users can use to orientate themselves in the software package](image)

The information at the bottom of each main screen allows users to orientate themselves as to the name and number of the topic they are using, the total number of main screens in that topic and the number of the screen they are currently viewing.

The following problems were identified with mapping system used in the software:

- **Some of the information at the bottom of each main screen is redundant.** For example, elements 1 and 2 offer users similar information: they let users know what screen they are on and the total number of screens in that topic. Both elements allow users to move from one screen to another, although element 2 only allows users to move forward or back by one screen. One of these elements would have sufficed. Similarly, screen elements 3 and 4...
essentially tell users what topic they are in. Screen element 4 offers users additional informational about how many topics there are in the package, and is thus marginally more useful than element 3, but the reason why both screen elements are needed is not readily apparent. The redundant information serves only to make the screen design more complicated for users to process.

- **The total number of screens given is not an accurate reflection of the total number of screens in that topic.** The number of screens given in screen elements 1 and 2 refers to the number of main screens only, and does not take into account the number of sub-screens. This could be a problem if users were trying to work out how long it might take them to work through a topic. According to the information at the bottom of the main screens for Topic 132 (see Figure 34 on page 149), the topic has a total of 10 screens, but the actual total number of screens is 21 when the sub-screens are taken into account. Similarly, Topic 3 has 25 main screens, but the total number of screens (main screens plus sub-screens) is 85.

- **Users are not able to see where they are in a series of sub-screens.** To see which main screen they are on users can refer to the bottom right-hand corner of a main screen where the number of the main screen they are on will be highlighted in purple (see Figure 55 on previous page). Users can also see the number of the current main screen (given out of the total number of main screens in that topic) as shown in Figure 55. These two features are not present on sub-screens, however, so users may find it difficult to work out where they are if there is a whole series of sub-screens. There can be any number of sub-screens to a main screen, and as they are not numbered users do not actually know where they are when on a sub-screen, or how many sub-screens there are to any one main screen. For example, I found myself lost in Topic 124, where a single main screen has several sub-screens with additional information about the topic dealt with on the main screen (accessed via a *Curiosity* icon, see Chapter 11, Figure 45, page 174).

- **Users are not able to track which screens they have already viewed.** There is no provision in the software for users to see which topics or units they have viewed.

The mapping system for the software package only provides the user with the opportunity to know where they are in the package and where they can go, but it fails to help users track where they have been. The mapping system is not sufficiently detailed to help users to effectively orientate themselves within the software. Herrington and Oliver (1995) suggest the use of path trails and simple graphics to orientate users within a package. A path trail could have been used in the software to aid users in tracking their path through the software.

### Screen appearance

The reader is reminded that screen appearance is one of three dimensions of interface design evaluated in this study and that screen appearance has four sub-dimensions, text design, screen layout, graphics and images, and colour.
Text design/presentation

The legibility of on-screen text is a significant factor influencing users’ comprehension of what they are reading (Reynolds, 1979; Oliver & Herrington, 1995). Designers working with electronic text face a number of restrictions compared to printed text, e.g. the relatively small amount of electronic text that can be fitted in per screen (Hartley, 1987). The text design in the software package evaluated was found to largely adhere to the guidelines elicited from the literature (see Appendix AJ for the section of the completed Interface Design Checklist dealing with text design).

The text design in the software followed the guidelines in the literature in the following ways:

- **The typeface and size of font used in the software package are easy to read.** The typeface used is the sans serif Arial face. Some researchers (e.g. Reynolds, 1979) claim that the simple form of sans serif typefaces aid legibility.

- **Variation in styles of type font is used effectively.** According to Reeves (1994) changes in style of the typefont should only be used to draw attention to important information. Marcus (1992) points out that such changes in style must be used discerningly so as not to add to the complexity of the screen design. A larger font size has been used effectively in the software to draw users’ attention to headings. Both boldtype and italics have been used effectively to focus on important concepts, although the use of italics is inconsistent.

- **Upper case letters are used for purposes of emphasis only.** Text in capital letters is believed to reduce the legibility of the text (e.g. Reynolds, 1979; van Nes, 1986; Hartley, 1987; Isaacs, 1987). Upper case letters have only been used once in the software, to draw attention to a hyperlink in a graphic.

- **The screen is appropriately covered with text and graphics so that it does not appear crowded.** According to Reeves (1994), researchers suggest appropriate screen coverage is between 25-40% of the screen. In all five topics all of the screens have appropriate screen coverage, which was judged by how crowded the screen looked.

- **Highlighting techniques are used purposefully.** Highlighting techniques are largely used purposefully in the software package. The only exception to the purposeful use of highlighting is the flashing symbols in one graphic, which serve no discernible purpose. The graphic in which the flashing symbols are used is shown in Figure 55. Reeves (1994) suggests avoiding the injudicious use of blinking, as it may prove distracting to users. I found the flashing symbols in the graphic to be misleading: Initially I thought I had to click on the symbols because my attention was drawn to them, only to find out later that I had to click on the words above and below them to change the picture in the graphic.
The following principles relating to text design were violated in the software package:

- **The text in the software package is not always appropriately justified.** Although the text is appropriately aligned on the screen with respect to kerning and leading, the justification type is inconsistent across the five topics. The ideal situation is for text to be left-justified. According to Reeves (1994) left-justification supports the general way Westerners read. In left-justified text “each line is filled to the nearest whole word” (Reynolds, 1979), which maintains regular spacing between words and facilitates reading. The text in the software is sometimes left-justified, but sometimes not. The text on the screen in Figure 56 (see above) has been wrapped around the image to give a slanted left-hand edge to the text. This text cannot be described as left- or right-justified. Figure 56 (overleaf) shows an example of a screen with text that has been wrapped around the circular lines surrounding an image, creating a ragged left-hand edge. It is not clear why the text has been wrapped around the circular lines. The irregular edge of the wrapped text at the bottom of the screen in Figure 56 contrasts with the smooth edge of the left-justified text at the top of the screen. I found the left-justified text at the top of the screen easier to read.

- **The number of words that should be used per line is often inappropriate (exceeding 8 – 10 words per line).** The length of lines is an important factor influencing the legibility of text. Very long lines make it difficult for users to move from one line to the beginning of the next line (Reynolds, 1979; Heines, 1984, cited by Isaacs, 1987; Reeves, 1994). The majority of screens for four out of the five topics have an appropriate number of words per line, but one topic has fewer than half of the screens having an appropriate number of words per line (Topic 3 – 36%). The screens which contribute most to the inappropriate number of word per line are the screens with full screen photographs, where the text is very small so more words can be fitted in per line. The software should have followed this guideline more closely to enhance text legibility.
Barring the inappropriate number of words per line on some screens in the software, and the inconsistent use of justification, the text design is effective and should not hamper legibility and comprehension of the text.

**Screen layout**

The completed section of the *Interface Design Checklist* dealing with the layout of the screens in the software package is shown in Appendix AK.

The software was found to adhere to three of the four guidelines for screen layout elicited from the literature:

- **The screen display comes across as balanced and symmetrical.** According to Reeves (1994), balancing portions of text with graphics helps to focus the learner’s attention, and looks more attractive. All of the screens in the five topics have portions of text balanced with graphics, which contributes to the screen displays being balanced and makes the screens look attractive.

- **There is sufficient “white” space in the structure of the display to make the display easy to read.** The presence of open space on screens makes text easier to read (Reeves, 1994). The amount of open space on the screens in the five topics was judged to be appropriate, but the presence of watermarks on the main screens makes the screens very busy and often proves distracting. The watermarks are diffuse and often interfere with the legibility of text and images. There is however, sufficient “white” space to make the screen displays easy to read. The issue of the watermarks will be dealt with under the “*use of colour*” sub-dimension.

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10 In this package the “white” space is green.
• The layout is logically organised with top-to-bottom and left-to-right sequencing. With the exception of one screen, the screen layout in the five topics was found to be logically organised. The first screen of Topic 3 has the content on the left of the picture. This screen has been juxtaposed with the first screen from one of the other four topics in Figure 57 so that the reader can compare the layout on the two screens. The layout on the first screen of Topic 124 is more logical because the picture is on the left and the content on the right (see image on right in Figure 57).

The one screen-layout principle which was violated in the software is the inconsistent location and function of screen elements like textual signals and cues. Consistent screen elements make multimedia programmes easier to learn and easier to use (Brooks, 1993, cited by Oliver & Herrington, 1995). Most of the inconsistencies in the use of screen elements arise because of the differences evident in Topic 3 compared to the other four topics, as previously discussed (see bottom of page 332). The differences between the screen elements are evident in the comparison of the first screens of Topic 3 and Topic 124 (as representative of the first screens of the other four topics) in Figure 57. In addition to the differences in the organisation of the content list and the picture between the two first screens, the different appearance and location of the screen elements give the first screen of Topic 3 a very different ‘look’ to the first screens of the other four topics. The inconsistencies in the use of screen elements could make it more difficult for users to learn how to use the software package.

**Graphics and images**

According to Oliver and Herrington (1995)

> Instructional designers frequently use graphics and images to enhance the appearance and appeal of instructional materials. It is important to make decisions concerning the usage and placement of images based on the needs of the learner (Oliver & Herrington, 1995, p. 8).
Duchastel (1978) describes images as being ‘attentional’ when they attract users’ attention by making the text look more interesting, or as being ‘explicative’ when they illustrate some aspect of the text they accompany or they “add something which is not clearly expressed in words” (Duchastel, 1978, p. 38). Attentional images have a purely motivational benefit. Explicative images may have both instructional and motivational benefits (Duchastel, 1978). Three guidelines for the effective use of explicative images (also referred to as ‘illustrative’ images) were elicited from the literature (as given in Appendix P – Guidelines for evaluating interface design). These guidelines, briefly restated here, are that illustrative images should be simple and clear, they should have their key components labelled, and they should have a clear purpose.

Two types of images are used in the five topics: photographs and non-photographic images (which I will refer to as ‘graphics’). The section of the completed Interface Design Checklist for the use of graphics and images in the software is shown in Appendix AL. The photographs used in the five topics are simple, clear and often quite eye-catching. None of the photographs have any labelling, which is acceptable because the photographs are used mainly for attentional and illustrative purposes. While all the photographs in the five topics follow the guidelines for the use of images, not all the non-photographic images do. Four of the 11 graphics in the five topics do not adhere to any of the three guidelines elicited from the literature. These four graphics are discussed individually below. The graphics concerned have been given names according to their intended function to make it easier for me to refer to them and for the reader to relate to them.

- The “ecosystem” graphic (from Topic 124) consists of three parts:
- The screen showing the first picture of the abiotic components of an ecosystem is shown in Figure 58. The word “biotope” above the graphic appears unrelated to the graphic.

![Figure 58. The first part of the ecosystem graphic in Topic 124](image)

- The second part requires users to click on the highlighted word “biocoenosis” to the left of the graphic shown in Figure 58. Clicking on the word “biocoenosis” changes the picture on the screen to show the biotic components of an ecosystem (see Figure 59 below). There is no instruction or labeling making it clear to users that this is what they are required to do.
- The third part requires users to click on the highlighted word “ecosystem” to overlay the “biotope” and “biocoenosis” images to form a complete ecosystem (see Figure 59 on the next page).
I encountered the following problems with the graphic. While the lack of instructions made it difficult for me to understand what I was meant to do, the absence of any labelling made it difficult for me to understand what I was seeing in the graphic. I had difficulty working out that the highlighted words are related to the graphic. The highlighted words seem to convey a message of their own (that abiotic features and biotic features together form an ecosystem). It took me a couple of attempts to understand that I had to click on the highlighted words to change the pictures and that the final graphic consisted of the biotic features and abiotic features of an ecosystem being overlaid to make up a complete ecosystem. The flashing symbols between the highlighted words to the left of the graphic proved distracting: I did not know whether to click on the flashing symbols or the highlighted words. Interpreting the graphic is further complicated (in a South African context) by the use of the unfamiliar terms ‘biocoenosis’ and ‘biotope’. The common terms used in this country are biotic for biocoenosis and abiotic for biotope.

- The “energy flow” graphic (Topic 124) is shown in Figure 60 on the next page. The cycle shown in the graphic is an attempt at depicting the flow of energy between high energy organic compounds and low energy inorganic compounds. At first glance the graphic looks colourful and interesting, but I found it difficult to interpret.
The following difficulties with interpreting the “energy flow” graphic could prevent it from having any clear instructional or motivational benefit.

It is not clear what the significance is of the colours used in the graphic: the green area represents abiotic (‘biotope’) features, but I associate the colour green more closely with biotic factors (like plants and photosynthesis). The significance of the blue area (‘biocenosis’), which is supposed to represent the biotic factors, is obscure.

It is not clear which elements (in white text) form part of the energy flow cycle and which elements are entering or leaving the cycle. Sunlight, as the source of all energy, should be entering the cycle, but this is not clearly indicated in the graphic. The burst of light which represents the sunlight is situated far from the arrows representing the cycle.

The positioning and meaning of the “movement and heat” ‘circle’ is not clear. I interpreted this circle as representing forms in which energy may be lost from the cycle. Putting movement and heat together in the same circle makes them comparable to each other, which they are not. Movement is a process requiring energy, while heat is a form of energy. The “movement and heat” ‘circle’ is placed in the abiotic area of the graphic. While heat is an abiotic factor, movement cannot be regarded as an abiotic factor. In this context ‘movement’ is probably meant to represent the transformation of potential energy into kinetic energy in living tissue. Heat, which is a form of energy, may well be lost as a result of movement, but heat may also be lost as a result of urination, defaecation and respiration. The information shown in the graphic is thus incomplete.

The cycle is incomplete in that it does not show the process of photosynthesis during which the energy from sunlight is trapped in high energy organic compounds, nor does it show the process of respiration by which the energy is released from the food.
The ‘biome map’ in Topic 124 (see Figure 61). The map is meant to be showing the distribution of the different biomes. Users are meant to click on the names of the colours in the key in the top right-hand corner of the map to see the regions where the corresponding biome occurs.

There are three problems with the map:

- The key for the map is not headed, so it is not clear to users what they are supposed to do.
- It is unusual to have to click on the colour associated with a name in a key and not the name itself. I initially thought the graphic did not work, and only discovered, by accident, and after numerous attempts to make sense of the map, that I had to click on the colours in the key to see the regions where that biome occurs on the map.
- The information on the map is incomplete. Only four major biomes are shown, compared to ten biomes in reference books I consulted (e.g. Roberts et al., 1993).
- At first glance it is difficult to distinguish the colours on the biome map, because the colours on the map do not correspond well to the colours in the key provided. The lack of clarity of the colours on the map could be due to the pervasive dark-green watermark on this screen. The watermark could be affecting the way the colours appear on the map. Since this map
uses colour to show the distribution of the biomes, it would have been more effective to leave out the watermark to ensure the colours show up more clearly.

- The “waste production flow chart” (see Figure 62) shows where waste is produced in the production of goods for consumption and how the waste produced is removed to the atmosphere, water and soil. I found the following problems with this graphic:

![Figure 62. The “waste production” flow chart from Topic 132](image)

- The chart is too small (the whole flow chart occupies less than half of a screen). With all the information and arrows compressed into a small area, this makes for a ‘busy’ graphic which is difficult to interpret.

- The use of colour in the flow chart is not logical. While it can be understood that processes are shown in blue (like “acquisition of raw materials” “production of energy” and “production of goods”), and tangible objects “raw materials” and “goods” are in red, it is not clear why “energy” is also in red.

- The law of conservation of energy is violated in the graphic: it suggests that energy can be produced (see “production of energy” in Figure 60 on page 199). Another problem is that at the centre of the flow chart, there is a sequence which suggests that raw materials can result in the production of energy, which then leads to energy which can be used in the production of goods. This relationship implies that the same raw materials from which goods are produced are used to provide the energy needed to produce goods, which is confusing. An example to illustrate how this could happen would have been useful.

- The purpose of the flow chart is not clear. If, as the graphic shows, the conclusion of the industrial processes is the “safe storage of waste”, then this suggests that there really is no problem with waste. Without figures to support the assertion that the release of waste into the air, soil and/or water is a problem, and without some mention of the types of waste being produced, I find the topic of waste production as shown in the chart to be dealt with superficially.
In summary, the high proportion of photos (ranging from 80% of the images in Topic 133 to 100% of the images in Topic 135) suggests that the main purpose of the images used in the five topics is motivational and illustrative and not explanatory. Where explanatory images have been used, they have not been used to their full instructional potential. The four graphics (out of a total of eleven non-photographic images) discussed above are all colourful and appealing to look at, but their instructional benefits have been compromised by not being clear and simple, by a lack of clear labelling and instructions, and by incomplete and unclear handling of the content they were meant to convey. This means that only about two-thirds of the graphics in the five topics have the potential to promote conceptual understanding.

**Use of colour**

The use of colour can enhance the look of a screen. Pastoor (1990, p. 157) believes that colour should mainly be used “to improve the information acquisition and generation process”. Four guidelines were elicited from the literature about how colour should be used on the user interface to enhance learning (see Appendix AM for the section of the completed Interface Design Checklist for the use of colour in the software). The following issues reduced the effectiveness of the colour usage in the software:

- **There is insufficient contrast between the text and the background for many of the screens.** The percentage of screens per topic with good legibility ranged from 67% for Topic 135 to 95% for Topic 132. While three of the topics had percentages above 80%, it is unacceptable for 20% to 30% of the screens in a topic to be difficult to read. These are the reasons why legibility was compromised on some screens:
  - In Topic 3 the use of purple text for screen titles against a lighter purple background does not make for easy legibility. However, most of the screens in this topic are full screen colour photographs, so the percentage of screens with good legibility is still high (92%). In the other four topics light-coloured text (light-green or white with orange hypertext) is used against a dark background, which provides sufficient contrast for easy legibility.
  - The presence of a watermark on the screen interferes with the legibility of the text. The watermarks are often diffuse, spreading across both text and graphics and making them difficult to read or interpret. The effect of the watermark on interpreting the “biome map” graphic in Topic 124 has already been discussed (see Figure 61, page 200). The effect of the watermark in reducing legibility is most notable in Topic 133 (on 5 of the 15 screens [30%]) and in Topic 124 (on 4 out of 14 screens [29%]).

- **Colour is used for highlighting in ways that are distracting.** The number of screens where I found the use of colour for highlighting to be distracting ranges from 4% (Topic 3) to 14% (Topics 124 and 132). The effect of the watermarks has not been taken into account when judging this criterion, because they have not been used for the purposes of highlighting text or graphics. If the distracting effects of the colours used in the watermarks were taken into account, the number of appropriate screens would be much lower.

- **The software does not have a consistent colour coding scheme (which would make it easy to identify visual devices like menus and titles).** The use of colour coding to demarcate specific areas on the screen is well documented (see Pastoor, 1990). Brockmann
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(1991) advises that colour codes must be consistent. There is a lack of consistency across topics in the colours used for coding screen titles and image headings. The colour scheme used in Topic 3 differs significantly from the scheme used in the other four topics (see earlier discussion under “use of colour”).

Colour coding can have “unfavourable results” when the meaning of the colour code is not clear to users (Pastoor, 1990, p. 158). For four of the five topics there was at least one screen on which the purpose of using different colours was not clear. The Remember screens (“read and record” activities) have every alternate fact in a different colour, without there being any instructional or motivational significance to this.

- **The software uses red-green colour combinations.** No yellow-blue colour combinations were found on any screens in the five topics. However, there are two topics which have red-green colour combinations (14% of the screens in Topic 132 and 7% of the screens in Topic 133). Red-green colour blindness is an inherited defect which is more common in males than in females (1% to 8% of males are affected depending on race, but only about 0.4% of females (“Color blindness,” n.d.). People with this form of colour-blindness find it difficult to distinguish between red and green when these colours are combined. Despite the low use of red-green colour combinations, the guideline is not to use colour combinations which people who suffer from this form of colour-blindness may not be able to read.

In summary, colour has mostly been used effectively in the software in ways that will promote the information acquisition and generation process.

**Media use and integration**

As previously discussed, using multiple media (text, images, animation, audio and video) on the user interface of multimedia software results in a complex combination of stimuli which can affect how users comprehend the information on the interface. This section reports the findings from the evaluation of the last of the three user interface dimensions, media use and integration. This user interface dimension has two sub-dimensions, animation and media integration.

**Use of animation**

Mayer and Moreno (2002, p. 88) define animation as “a simulated motion picture”. These authors further define a simulated motion picture as a picture representing artificial objects (created by drawing or some other method of simulation) in which the artificial objects apparently move. The idea of a simulated motion picture distinguishes animations from videos, which are pictures depicting the actual (as opposed to apparent) “movement of real objects” (Mayer & Moreno, 2002, p. 88). Animations offer certain advantages over videos including simplified representations of material; control over the movement, colours and shapes used in the representations; and the use of highlighting techniques to draw attention to certain aspects of the representation (Stith, 2004). The movement involved in animations distinguishes animations from static pictures. Movement in animations can be used to depict processes changing over time (Rieber, 1994), which can, at best, only be implied in static graphics (Lowe, 2003). According to McClean et al. (2005) the use of animations to show the changes in processes over time helps learners to understand the relationships
between the important concepts in a process. While the benefits of showing the changes in processes over time can be applied to all fields of science (Stith, 2004), animations are useful in biology because they “provide a valuable way to communicate dynamic, complex sequences of biological events more effectively than text or static graphics” (O’Day, 2007, p. 221). Examples of the useful applications of animations in biology include depicting the interactions between biological molecules and the animation of cell processes like DNA replication and enzyme activity (e.g. Stith, 2004; Blystone & McAlpine, 2005).

The use of animation in multimedia instructional packages is complex. While many benefits of using animation have been put forward, (e.g. that the use of motion leads to longer-term memory [O’Day, 2007]), including temporal change in a graphic representation introduces a different set of “information processing demands” on learners (Lowe, 2003, p. 157). The additional and/or different processing demands must be managed in the design of the animation if learners are to benefit from the use of animation. According to Tversky et al. (2002) animations should meet the following principles to qualify as well-designed. Firstly, the structure and content of the animation should correspond to the desired cognitive or internal representation required by the software designers for the material to be learnt (known as the congruence principle). Secondly, the animated material should be readily and accurately perceived and understood by learners (known as the apprehension principle). I applied these two principles to the only animated graphic in the five topics (as shown in Figure 63).

![Figure 63. The only animation in the five topics](image)

The narrative accompanying the animations goes: ‘Avocet, little egret and purple heron visit the same ponds, but occupy different ecological niches. In practice this means that they have different eating habits’.

The content on the screen on which the animation is used introduces the concept of “ecological niche”, but neither the animation nor the narration would enhance learners’ understanding of the concept. The dynamic part of the animation involves an egret catching a blue fish in its mouth and then tossing the fish so the fish falls back into the water, to be picked up again by the same bird. The movement does not depict a process happening over time. Rather, the repetitive nature of the...
movement is both distracting and annoying. The narration does little to deepen learners’ understanding of the concept of “ecological niche”. The narration makes reference to the term “eating habits”, but does not indicate how the feeding habits of the three types of birds differ, i.e. that they feed on different organisms in the same pond so they are not competing for the same type of food. The purpose of the animation is difficult to discern, other than it including some movement so that it is not a static graphic. I found the repetitive nature of the movement used in the animation irritating, which could detract from any motivational value or instructional value the animation may have. The single animation is actually little more than a moving graphic. The simple nature of the ‘moving graphic’ means that it cannot be evaluated against the congruence and apprehension principles put forward by Tversky et al. (2002) for judging a well-designed animation.

As discussed above, animation appears to particularly useful in biology at the molecular or cellular level, where molecular interactions and cellular processes can be depicted. Although the content covered in the five topics does not fall within this ambit, there are two instances where processes are depicted which could have been easier to understand had the processes been animated. The first of these is the “energy flow” graphic (see Figure 60, page 199), where the relationship between the different parts of the cycle could have been clearer had the cycle been animated. The second graphic is the complex “waste production” flow chart (see Figure 62, page 201).

Dismissing the single graphic in the five topics as a moving graphic, animation has not been used effectively in the five topics, even where it could have made complex graphics easier to interpret.

**Media integration**

When evaluating the use of different media as an element of interface design, the literature suggests that where mixed media are used, the different media should be sufficiently close together on the screen (spatial integration) and that the media should appear on the screen at the same time (temporal integration) to avoid delivering conflicting messages. Ayres and Sweller (2005) suggest that integration of information by the designer reduces the need for mental integration by the user, thereby freeing up working memory resources for learning.

On all the sub-screens in the five topics, the text accompanying the pictures has to be called up separately, which means that, initially, pictures and text are neither temporally nor spatially integrated on these screens. It would have been more logical to have the text on sub-screens called up automatically: users need to read the description accompanying the picture to understand what the picture is showing. Having to call up the text on the sub-screens is confusing for first-time users (who don’t know they have to do this and are faced with pictures without accompanying text). Even when users know they have to call up the text, it is annoying to have to call up the text on every sub-screen.

Table 30 is a summary of how different media combinations are used on the main screens of the five software topics that were evaluated. A discussion of the different media combinations follows after the table.
Table 30. Summary of the use of mixed media on the main screens of the five topics*

<table>
<thead>
<tr>
<th>Topic</th>
<th>Screens with mixed media*</th>
<th>Audio only (pink screen)</th>
<th>Audio with changing photos</th>
<th>Audio and single graphic/animation</th>
<th>Audio with text (“Listen” icon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – How has man classified the world around him?</td>
<td>3/25 (12%)</td>
<td>2/3 (67%)</td>
<td>0/3</td>
<td>0/3</td>
<td>0/3</td>
</tr>
<tr>
<td>124 – An ecosystem is a working organisation</td>
<td>4/6 (60%)*</td>
<td>1/5* (20%)</td>
<td>0/5*</td>
<td>0/5*</td>
<td>1/5* (20%)</td>
</tr>
<tr>
<td>132 – Types of pollution</td>
<td>5/7 (71%)*</td>
<td>2/7* (29%)</td>
<td>1/7* (14%)</td>
<td>0/7*</td>
<td>3/7* (43%)</td>
</tr>
<tr>
<td>133 – Species dying out</td>
<td>4/6 (67%)</td>
<td>1/4 (25%)</td>
<td>1/4 (25%)</td>
<td>0/4</td>
<td>1/4 (25%)</td>
</tr>
<tr>
<td>135 – The nature necessary for living</td>
<td>4/6 (67%)</td>
<td>1/4 (25%)</td>
<td>2/4 (50%)</td>
<td>0/4</td>
<td>0/4</td>
</tr>
<tr>
<td></td>
<td>20/52 (38%)</td>
<td>7/23 (30%)</td>
<td>4/23 (17%)</td>
<td>2/23 (9%)</td>
<td>5/23 (22%)</td>
</tr>
</tbody>
</table>

# The assessment screens and sub-screens were not included in these counts because these screens are less likely to use mixed media.
* The counts include the Remember (read, listen and record activity) screen found in each topic.
**One or more screen(s) has two audio inserts.

The four media combinations used in the software are:

- **Audio with a single graphic or animation.** These graphics (which are not photographs) or animations remain on screen when the “Play” icon is clicked on. The “energy flow graphic” and the audio insert above the graphic are an example of this type of media combination (see Figure 60 on page 199). I found that these messages and graphics/animation complement each other.

- **Audio with a series of changing photographs.** These audio inserts play when the “Play” icon is clicked on (see Figure 64). The photograph in a circle on the screen changes to show different photographs which illustrate various aspects of the audio message. The audio and ‘changing photograph’ combinations work well. The photographs illustrate aspects of the video, so the two messages complement each other.

![Figure 64. A screen showing two of the three different combinations of media in the software package](image-url)

- **Audio with text.** Clicking on the “Listen” icon (see Figure 64) plays an audio insert which is a reading of the accompany text. Since the audio message repeats the text message it is redundant.

- **Audio with a photograph.** Typically, this combination of media involves a photograph which is accompanied by an audio insert. When the “Play” icon below the photograph is clicked on, the photograph that was on screen disappears and is replace by a ‘pink area’ (see Figure 65).
Learners’ attention is thus split between looking at the photograph or listening to the audio, which means that they will not be able to process the dual modes of information at the same time. The reason for the pink screen is not obvious (it may even be a technical error) and is confusing for users.

Figure 65. An example of the ‘pink area’ which replaces photographs when some audio inserts are played

An analysis of the information in Table 30 (the summary of the use of mixed media on the main screens in the five topics, see page 206) and the discussion of the four types of media combinations shows the following:

- A limited number of different types of media combinations are used on the main screens. The four combinations used all include audio inserts, either combined with photographs or text. There are no video inserts in the five topics, possibly because video takes up many bytes of space.

- The overall use of the four types of combinations involving audio is low: they are found on less than half (38%) of the main screens.

- More than 50% of the audio combinations used are not effectively integrated. Thirty percent of the audio combinations are actually audio messages on their own and not really audio combined with a photograph (the photograph is replaced by a ‘pink area’ when the audio plays). Twenty-two percent of the audio combinations used are redundant (those played when users click on the “Listen” icon). The redundant messages may well hinder learning (as will be discussed in more detail in the next section).

In summary, the software tends to rely more on photograph and text combinations than other media combinations. The extensive use of photographs in the five topics (especially on the sub-screens) is shown in Appendix AL. None of these photograph and text combinations are temporally or spatially integrated. Where other combinations are used (on the main screens), the combinations all involve audio. Less than half of these audio combinations have been used effectively.

As a multimedia package, the software does not appear to have fully exploited the potential of mixed media or of animation.
5.8.5 The multimedia strategies used in the software package to promote effective teaching and learning

The findings from evaluating the multimedia strategies used in the software package must be seen within the context of cognitive load theory. As previously stated (see pages 136-139), cognitive load theory provides a framework for investigating how the structure or presentation format of information is likely to affect cognitive processing of information to be learned (Sweller, 1994).

Research into the use of multimedia strategies to reduce cognitive load and enhance learning is ongoing (see Appendices R and S). Researchers (e.g. Bannert, 2002 and van Merriënboer & Sweller, 2005) point out that since 2000 the focus of research has shifted away from reducing extraneous cognitive load to finding instructional methods that reduce the intrinsic and increase the germane loads. An example of a method which is believed to reduce intrinsic cognitive load is the use of segmenting (breaking up presentations of narrated material into smaller sections which allows the learner to control the pace at which the material is presented) (Mayer & Chandler, 2001, cited by Mayer, 2005). Germane cognitive load can be increased by “encouraging learners to engage in conscious cognitive processing that is directly relevant to schema construction” (Kirschner, 2002, p. 5). The crux of the matter is that there are a number of strategies that instructional multimedia developers can use to enhance learning.

The completed Multimedia Strategies Checklist for evaluating the use of basic multimedia principles that can be used to enhance learning is included as Appendix AN, while the completed Multimedia Strategies Checklist for evaluating the use of advanced multimedia principles that can be used to enhance learning is included as Appendix AO. Despite the range of design features that can be used to reduce the cognitive load involved in processing information presented in multiple modes, only four of the eight basic strategies that should be used in multimedia instructional packages are present in the software (see Appendix AN), while none of the advanced principles were followed by the software designers (see Appendix AO).

It appears that the problem is not so much that the software developers have neglected to use the multimedia strategies to enhance learning, as that the intention to use the strategies has been subverted by poor design of many of the elements. Gains in the germane cognitive load achieved by the use of four of the eight basic principles (see Appendix AN) is likely to be offset by the high extraneous load caused by learners having to process, for example

- unclear pictures. Although pictures are used to augment words many of the pictures are unclear (see biome map, shown in Figure 61, page 200, where the presence of the watermark over a large part of the screen makes it difficult to interpret the colours on the map, and Figure 60, page 199 and Figure 62, page 201, for other examples of graphics without clear instructional or motivational benefits).
- media combinations that are split temporally and spatially.
- redundant information.
- the inconsistent and limited use of signals to draw learners’ attention to important information.
The subversion, through poor design, of the designers’ possible intention to use appropriate multimedia strategies to enhance learning can be further illustrated by the way interactivity is used in the five topics. One of the claims made by the software developers is that the package is interactive. Computer-based media qualify as interactive systems by virtue of their unique ability to initiate interactions with learners (when compared to some television programmes and films) (Laurillard, 2002, cited by Evans & Gibbons, 2007). Evans and Gibbons (2007, p. 1149) describe a computer-based lesson as interactive if “computer-initiated activity” forms an intrinsic part of the lesson and as “non-interactive if it requires little or no computer-initiated activity”. Computer-initiated activity refers to an activity that requires a response from users and for which the computer provides feedback (Evans & Gibbons, 2007). In applying the descriptions of interactivity and non-interactivity to the content I evaluated, I found the use of interactivity in the five topics to be limited to

- the two sorting activities in Topic 3. These activities were found to have limited potential to contribute to meaningful learning because they can be completed by trial-and-error (see Appendix AE for an analysis of types of activities in the five topics).
- the read, listen and record activities found in each of the five topics. These activities, which have the potential to be interactive, do not work (see Appendix AE for an analysis of types of activities in the five topics).

While there is evidence of the intention to use interactivity as a multimedia strategy in the five topics, poor design of the activities subverts the use of interactivity. Interactivity is believed to be useful when combined with animation so that learners can control the pace of the animation (see Appendix S). The use of animation in the software, which is limited to a repetitive movement in a single graphic rather than showing a process changing over time, does not lend itself to the use of interactivity.

In summary, of the use of the research-based principles which have been formulated for their effect on multimedia learning (as given in Appendices R and S), the designers of the software package appear to have followed only half of the basic multimedia principles and none of the advanced principles.

5.9 CONCLUDING REMARKS ABOUT THE EVALUATION OF THE EDOROM PACKAGE

After a comprehensive evaluation of the software package, according to design principles elicited from the literature, the EduRom package was found not to fully meet the claims made by the designers that it could support South African teachers with implementing the changes required by a new curriculum. The designers had claimed that the package “provides the answer to the latest curriculum”, “provides interactive educational software”, offers “continuous evaluation” and “cover(s) the majority of the new curriculum, based on OBE and e-learning principles”. However, the evaluation revealed that, firstly, the package did not adequately promote all of the requirements of the new Life Sciences curriculum. Of the seven curriculum requirements evaluated (two of the nine were thought not to be applicable to computer applications, so were not evaluated) the one most adequately met was that content to be taught must be relevant to learners. Most of the software content relating to biodiversity was found to be relevant to South African learners. However, the relevance of the content
appeared largely due to the nature of the topic, and not because of any conscious effort by the
designers to select content that would be relevant to South African learners. The remaining six
curriculum requirements were judged not to have been adequately met. For example, the assessment
activities in the package were not found to be useful because they used only lower order cognitive
skills and offered limited feedback.

Secondly, the evaluation of the extent to which the software could help teachers teach a new section
of work revealed a number of weaknesses in the software design for both the content coverage and
the pedagogical strategies used, which meant that the software would not have been suitable as
support material for teachers.

Thirdly, the EduRom package, despite its promise of being ‘interactive’ and being based on ‘e-
learning principles’, was found to make very limited use of animation, with only one graphic in the five
topics evaluated being animated, and this in a way that was judged not to be effective. The package
also used only four of the eight basic multimedia principles to enhance learning identified from the
literature and none of the advanced multimedia principles.

The most effective feature of the EduRom was the attractive look of the user-interface. A number of
features contributed to the pleasing look of the interface, e.g. the use of light-coloured text (light-green
or white) against a dark background; appropriate amounts of ‘white’ space; the balanced, symmetrical
layout of the screens, and the use of large colourful graphics. However, as Wurmann (1989, cited by
Brockmann, 1991) warned, aesthetics must not be confused with effectiveness. The interface design
of the software package does not fully adhere to the guidelines elicited from the literature for the four
interface design features evaluated in this study. Within the context of this study, the failure to follow
these guidelines suggests that, despite its attractive appearance, the interface design of the software
could hinder the ability of the software to promote effective learning.

The software evaluation thus revealed a number of problems with the instructional package which
limited its use in supporting teachers to use the new curriculum practices, or in teaching the new topic
of work effectively. This could explain why the software package was not used by teachers at the case
study school (as discussed in the previous chapter – see pages 102-105), underscoring the
importance of software quality as a factor influencing teachers’ use of computers for teaching.