Chapter 6. An Investigation of the Enabling Features of the Oz Soils CD Program to Scaffold Transfer of Conceptual Understandings from Independent Learning Contexts to Laboratory and Real-life Contexts

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1. Introduction

Oz Soils is a CD-ROM based interactive multimedia program that assists students in understanding the fundamental concepts and processes of soil science. Funded by CUTSD and developed in 1997 at the University of New England, the 18 teaching modules have been integrated into the teaching curriculum of Soil Science 211 (internal), and Soil Science 212 (external)). Oz Soils makes use of interactive animations, still graphics, and text, and includes interactive self-assessment questions.

A basic knowledge of how soil functions and interacts with other ecosystem components is essential for students in a wide range of disciplines, and Oz Soils is a learning resource that contains modules explaining the mechanisms of soil chemical, physical and biological processes. The introductory second year soil science unit is a core component of degrees in Rural Science, Natural Resources, Environmental Engineering and Environmental Science. It is also taken as an elective by students from other courses. In third year, students focus more closely on soil management issues in relation to the nutrient and hydrological cycles, soil contamination, and soil erosion. At final year and graduate level, students can choose from a number of elective units which emphasise application of knowledge gained in earlier years to soil management issues and case studies.

1.1 Context

The Oz Soils CD-ROM presents students with still graphics, animations and text to explain core concepts, followed by self-assessment questions. If the student has failed to understand a concept, the self-assessment questions will demonstrate this, and she or he can re-examine the instructional material. Understanding mechanisms of soil processes is facilitated by the use of animations, which can illustrate the processes in a more effective manner than static print media. For example an animation showing the exchange of cations at a charged clay surface leads to an understanding of the process and provides a conceptual basis for the laboratory procedure for measuring cation exchange properties of soils. The program is structured so that the individual processes are linked together, and can be seen as part of a whole. For example, the components of nutrient cycling in soils are modules within the overall nutrient cycle, and the combined influence of the processes on the overall cycle is illustrated for several common plant nutrients. This sense of linkage is hard to achieve in a sequence of lectures spanning a semester.

Soil profiles and the associated landscapes from all over Australia are presented to the students, and they are able to explore soil-environment interrelationships by being led through a sequence of questions and answers. This process simulates the student-teacher dialogue that takes place during field trips. Logistically it is impossible to visit sites remote from the campus, and there is currently not even a satisfactory introductory university textbook which describes the relation of Australian soils to their environment.

1.2 Background: Literature Review on Use of Multimedia to Support Learning

Najjar (1996) reviewed studies from a wide variety of fields, providing empirical support for the assumption that multimedia may be able to help people learn more information in less time that traditional classroom lectures or sole text-based learning. This study stated that learning, using multimedia resources, is most effective, (1) for learners with low prior knowledge or aptitude in the subject being learned; (2) if the media clearly support one another; and (3) if the multimedia information encourages the dual coding of information. Dual coding theory (Paivio, 1991) encompasses the concept of information being processed by human memory through one of two generally independent channels. Verbal information such as spoken words or text is processed through one channel and nonverbal images such as illustrations and environmental sounds through the other channel. According to the dual coding theory, learning is more effective when information is processed through both channels (referential processing) than when only one channel is used. Referential processing creates more cognitive paths that subsequently can be followed to retrieve the information (Paivio, 1991)

Novice learners appear to be able to take most advantage of resource materials in multimedia form because the dual coded text and pictorial information helps in creating a conceptual framework for a particular learning issue (Mayer, 1992, 1995). Additionally, learners with low prior knowledge have difficulty with deciding which is the more important information. Multimedia can be a powerful tool to focus the novice learner on such information. Laurillard (1993) argues that multimedia resources containing self-assessment questions can address most of the requirements for effective learning, and are a substantial improvement over sole reliance on lectures and printed material. Najjar (1996) also points out the advantages in self-paced learning and stimulation due to the novelty of multimedia materials.

Recent examples of computer-assisted learning (CAL) programs in science education which incorporate high-quality learning strategies are "Investigating Lake Iluka" (Corderoy, 1993; Hedberg, 1994) and "Exploring the Nardoo". Both programs are based on the concept of an information landscape that incorporates the physical, chemical and biological properties of virtual ecosystems (in the given examples, a coastal lake environment and a river system, respectively). The explorer/learner is given some problem solving strategies to investigate this information in a variety of ways and hence to come to an understanding of the basic ecology concepts embedded in the package. The problem solving nature and the open-endedness of these packages facilitate the development of higher order thinking skills. The role of the teacher to guide students in evaluating issues, interpreting conflicting information, and exploring alternate sources of information is most important for this type of technology resource, as learners can as easily come to an incomplete or incorrect understanding of the embedded concepts. In contrast, Technology supported environments with a closed well-structured information content such as "The Dynamic Rainforest" (CSIRO, 1996) and "Insects - a world of diversity", offer a more autonomous learning approach. These packages are most suitable to introductory level learning material.

1.3 Evaluation of Technology-supported Environments

Attempts to evaluate the extent to which technology supported environments improve learning are fraught with methodological problems (Draper, 1996). Gunn (1996) has recently pointed to the "extreme difficulty" in applying rigorous scientific experimental methods to evaluation of the educational effectiveness of Technology supported environments that are used as an integral part of a university course. She suggests that "there are too many individual and extrinsic influences at play for these factors ever to be considered as controllable variables". For example, if one attempts to assess whether part of a particular computer-based course has improved student learning, one approach is to establish a suitable control group of students who are not exposed to the program. However, there are major practical and ethical difficulties associated with this if one attempts evaluation in naturalistic settings. On the other hand if one looks at a technology supported environment in isolation, by testing its educational effectiveness on subjects who are not enrolled in the course, then there are problems in finding an appropriate group of students (matched, for example, in motivation and background knowledge to the enrolled students) and in relating the results to how the learning resource would perform when integrated with all the other resources of the course.

An alternative approach is to adopt the holistic, learning centered framework for the whole evaluation as suggested by Alexander & Hedberg (1994) and modified by Bain (1999). The framework suggests several phases of evaluation (from initial design to implementation) against which evaluation processes can be mapped. These are outlined in Table 6.1, and mapped against the aspects of the CD-ROM package that are the subject of the study.

1.4 Technology as Scaffold for Learning

In order to investigate student learning, the research team also applied learning theory in the evaluation of the CD-ROM resource. An aspect which has recently become of interest is how computer programs are able to scaffold learning in a science learning environment which involves lectures, laboratory classes and field work. The term 'scaffolding' is increasingly used to describe certain kinds of support which learners receive in their interaction with experts, teachers and mentors as they develop new skills, concepts or levels of understanding. The term scaffolding was originally coined by Wood, Bruner, & Ross (1976) as a metaphor to describe the effective intervention by a peer, adult or competent person in the learning of another person. Bruner explicitly relates the term scaffolding to Vygotsky's concept of "the zone of proximal development", that is the actual developmental level of the learner compared with the level of potential development that can occur with guidance or collaboration with a more competent person. The mechanisms for assisting learner cognition through the zone of proximal development have been extended greatly by technology applications and contemporary research (McLoughlin, 1998; Oliver, 2001). Originally, the teacher’s role was conceived as providing scaffolded assistance through modeling, contingency management, cognitive structuring and feedback (Tharp, 1988). Through modelling, tasks, skills and concepts can be demonstrated while retaining complexity and authenticity, so that learners can become engaged in the acquisition of new skills. Contingency management is concerned with recognising and rewarding learner actions, while feedback enables students to compare themselves to others. With practice, these mechanisms are internalised and become metacognitive strategies for students to regulate their own learning.

1.5 Aims and Research Questions

The present project formed part of the CUTSD project entitled "Staff Development in Evaluation of Technology-based Teaching Development Projects: An Action Inquiry Approach". The capability of Oz Soils to provide conceptual scaffolds which facilitate understanding of soil concepts and processes in laboratory and real life situations was investigated. This involved developing and carrying out an evaluation, and analysing the resulting data. Specifically, five research questions were addressed:

Table 6.1. Phases of evaluation.

Phase	Focus	Application to Oz Soils CD-ROM
Analysis and design	Curriculum	The curriculum was analysed to indicate how the CD-ROM would support learning outcomes
Development	Formative monitoring of the learning environment and learning processes	Throughout the semester, student usage of the CD-ROM was observed and measured in order to establish how it scaffolded student learning
Implementation	Summative evaluation of learning process and learning outcome as intended	Evidence was sought on the impact of the CD-ROM on student learning
Institutionalisation	Impact and sustainability of the innovation in the context of the whole course	The sustainability of the use of the CD-ROM was considered in the light of the evidence gained from evaluation.

1. What cognitive and conceptual scaffolds characterise the CD-ROM resource Oz Soils?
2. What evidence is there of transfer effects from individual study of the CD-ROM to laboratory tasks?
3. How useful do students perceive the CD-ROM to be in their learning?
4. What evidence is there in student learning journals and in bulletin board discussion of understanding of key concepts?
5. On the basis of the evaluation of the student learning and transfer, what recommendations can be made to enable integration of the CD-ROM resource into a tertiary study unit to foster independent learning?

By seeking to answer these questions we aimed to achieve an improved understanding of appropriate evaluation methodologies for a computer based teaching program.

1.6 Stages of the Project and Theoretical Grounding

The methodological difficulties associated with evaluation of technology supported environments, as discussed above, indicated that a controlled experiment, of the type familiar to physical scientists, would have been inappropriate for the present evaluation. Rather, a qualitative approach with triangulation of data was taken, with different types of evidence being gathered from students and the learning context throughout the semester. These are outlined as the stages below, which also follow the chronological order of data collection.

Stage 1

Using the concept of scaffolding derived from social constructivist theory expounded by Vygotsky (1978) , an analysis was made of all forms of scaffolding on the CD-ROM. These scaffolds, or learning supports were linked to the intended learning outcomes of the program.

Stage 2

The students (n=64) who were using Oz Soils, and whose learning was being investigated were enrolled internally in Soil Science 211 during the second semester of 2000. Soil Science 211 is a core, introductory unit for degrees in Rural Science, Agriculture, Natural Resources and Environmental Science.

Prior to a laboratory practical class, students were required to study, in their own time, a module from Oz Soils which explains concepts and processes relevant to that class. In the laboratory, students were given a range of manual and written tasks to perform in order to assess their understanding of key concepts, skills and calculations. During this time, students were asked to complete a questionnaire regarding the effectiveness of the CD-ROM in assisting their preparation for the practical activities. They were also asked to identify graphic images from the Oz Soils CD-ROM and rate the degree to which the graphic clearly illustrated the concept.

Stage 3

Following the laboratory session, students are always required to complete, in their own time, an online quiz pertaining to the class. As part of the present evaluation, an extra "transfer task" question was included in four of the post-practical quizzes which aimed to test the ability of the students to apply the concepts to solving real world soil management problems. In addition, a reflective survey was included in the online quiz.

The initial plan to evaluate student understanding of concepts from bulletin board discussions (research question 5) had to be abandoned due to difficulties in getting students to contribute postings to the bulletin board. The reserve shown by these second year soil science students contrasted markedly with the ebullience of bulletin board discussion by students in a fourth year soil science unit, as well as the behaviour of students in some Arts units, and warrants further investigation.

Stage 4

Students from the last practical class were asked to volunteer for the focus groups. Three mixed-sex focus groups were formed with twenty-two students involved in the discussions. The students were not asked to identify themselves.

The following questions were used as the basis of group discussion. The focus group sessions were tape recorded and an administrative assistant transcribed the responses and discussions for analysis by the research assistant.

- What do you understand by the term scaffolding?

- Can you identify any incidences of scaffolding of your study materials or class activities in the Soils 211 course that assisted in your preparation for laboratory exercises?
- What are they and how have they helped (not helped) you to learn and understand the concepts involved in the practical exercises?
- Can you identify examples of scaffolding used in the Soils CD-ROM that contributed to being able to participate in the practical class?
- Has the process of online evaluation assisted/ hindered you in learning in any way?
- Do you have any suggestions of ways that scaffolding might be better incorporated into the unit study material?
- Have you changed your learning habits in any way during your participation in the introductory Soils unit?

1.7 Research Team

At all stages of the evaluation the project mentor (Dr Catherine McLoughlin) ensured that the methodology was consistent with current educational theory and research practice. Dr Heiko Daniel (Senior Lecturer in Soil Physics) and Dr Peter Lockwood (Senior Lecturer in Soil Science) designed the questionnaires and reflective questions with input from Cherry Stewart (Educational Research Assistant). Soil Science 211 is taught between Peter (Unit Coordinator) and Heiko. The questionnaires and interviews were carried out by Cherry, who had no teaching role in the unit, and was presented to the students as an independent researcher who had no influence on grades.

Q1. Analysis of the cognitive and conceptual scaffolds that characterise the CD-ROM resource Oz Soils:
Data collected for this question was based on:
- literature review
- analysis of CD-ROM scaffolds in relation to learning tasks
- questionnaires to students
- focus group questions

Q2. Evidence of transfer effects from individual study of the CD-ROM to laboratory tasks:
- tutorial survey questions to students asking for feedback about the usefulness of the CD-ROM
- post-test questionnaire
- focus group questions
- performance in exercises

Q3. Student perceptions of the CD-ROM in supporting their learning:
- tutorial survey questionnaire
- post-test question asking students to comment on their performance in exercises
- focus group questions

Q4. Evidence available in bulletin board discussion of understanding of key concepts ?
- Post-test questionnaire
- tutorial survey questionnaire
- focus group questions

Q5. What recommendations can be made to enable integration of the CD-ROM resource into a tertiary study unit to foster independent learning?
- analysis of data
- action research cycle

Table 6.2. Instruments used for evaluation.

Instruments	N*	Qualitative	Quantitative
Analysis of CD-ROM Scaffolds	1	Yes	Yes
Student Survey — Embedded questions in tutorial	3	Yes	Yes
Questionnaire — Post-test survey	4	Yes	Yes
Focus groups	3	Yes	No
Transfer task: Quiz results	4	Yes	Yes

N=Number of incidences of data collection from students

2. Data Analysis

***1.** What cognitive and conceptual scaffolds characterise the CD-ROM resource Oz Soils?*

Following the initial literature search, the research assistant constructed a table of relevant scaffolding strategies devised from the work of Beed, Hawkins & Roller: 1991, Rosson & Carrol:1996, Hmelo & Guzdial: 1996, Bliss, Askew & Macrae: 1996, Jackson, Krajcik, & Solway:1998, Oliver:1999, Collis, Winnips & Moonen: 1999, Chung:2000, McLoughlin:2000. An instructional design analysis of the Oz Soils CD-ROM indicates that some scaffolding techniques have been used. These are not regularly structured throughout the multimedia resource, but individual examples of scaffolded techniques are evident in various sections. Researchers found evidence of six scaffolded strategies used in the two Oz Soils modules relevant to the lab practical activities covered in this project. Table 6.3 lists the strategies identified, the particular topic areas which contain the strategies, and the number of instances examples of these strategies were found.

The graphics (illustrations, animations, photographs, and diagrams) and self-test questions (feedback provided on correct answers only), are considered the major form of scaffolding used on the Oz Soils CD-ROM were considered the major form of scaffolding used in the resource. In the research activity, students were asked to assess the value of the graphics, text and self-assessment activities in the modules relating to each of their lab practical activities. Student responses on the survey indicated a mixed opinion regarding the usefulness of these. Figures 6.1, 6.2 and 6.3 plot the relative effectiveness of the graphics (animation, photographs, illustrations) that were provided for each of the modules for phase relations, soil texture, and soil chemistry on the Oz Soils CD-ROM. As illustrated by the graphs, about one third of the students used the CD actively, in preparation for the practical class; about one third were ambivalent about its usefulness, and another third did not use the CD at all. Discussions in the focus group identified that these students did not refer to the CD at all for reasons of time and access. For these students multimedia resources were not considered a study option as it required effort and planning to access the computer labs and to use the CD.

Table 6.3. Type of Scaffolded activities used on the Oz Soils CD-ROM.

Types of scaffolds used on Oz Soils CD-ROM	Oz Soils Topic using scaffold	# of instances
Contextual (placing concept into real world)	Soil Structure Hierarchy Aggregates Absorbed Ions	2 3
Modeled (provided expert performance, view map, graph, chart or table)	Soil Structure Hierarchy Soil Texture Aggregates Infiltration & Water Movement Absorbed Ions	8 8 9 1 9
Sequencing (time / procedural)	Soil Texture Aggregates Infiltration & Water Movement	7 3 8
Self-test question with performance feedback (multiple-choice / calculation)	Soils Structure Hierarchy Soil Texture Aggregates Soil Strength Infiltration & Water Movement Absorbed Ions	4 6 4 6 6 8
Comparison / contrast of graphics	Soil Structure Hierarchy Soil Strength Infiltration & Water Movement Absorbed Ions	1 8 12 3
Feedback that provided support information regarding correct or incorrect understanding of concept	Soil Structure Hierarchy Soil Texture Aggregates Soil Strength Infiltration & Water Movement Absorbed Ions	6 6 4 6 6 6

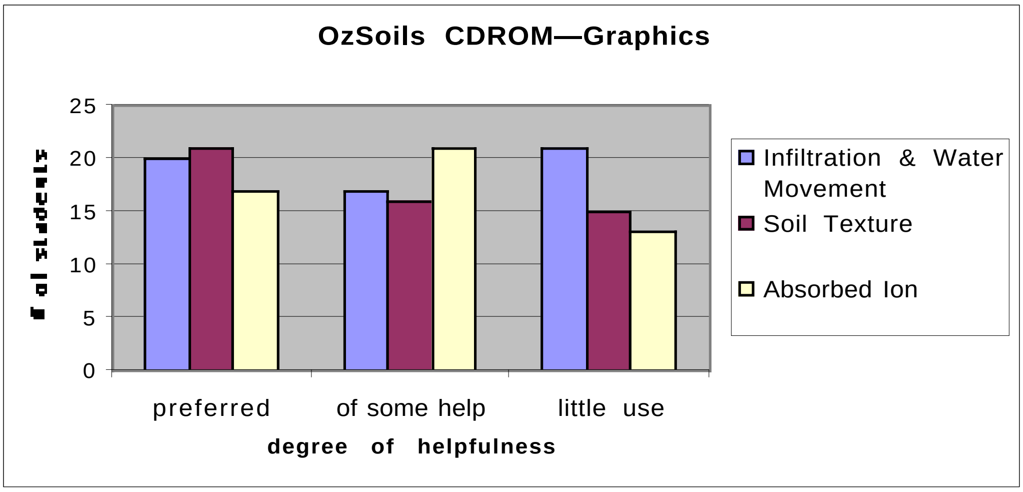

Figure 6.1. Student perceptions of the usefulness of Oz Soils graphics to their learning.

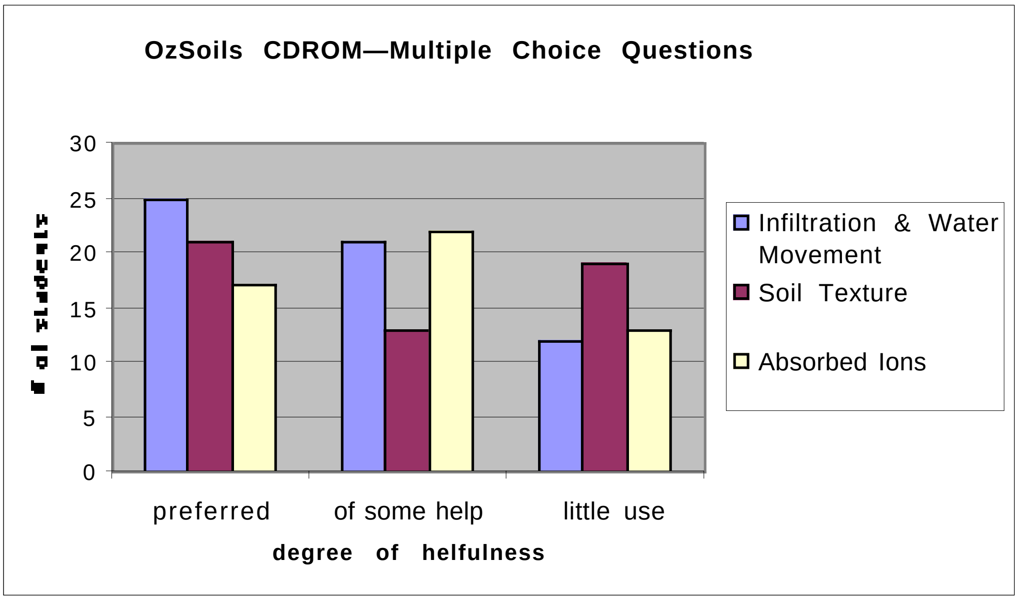

Figure 6.2. Student perceptions of the usefulness of Oz Soils self-assessment activities to their learning.

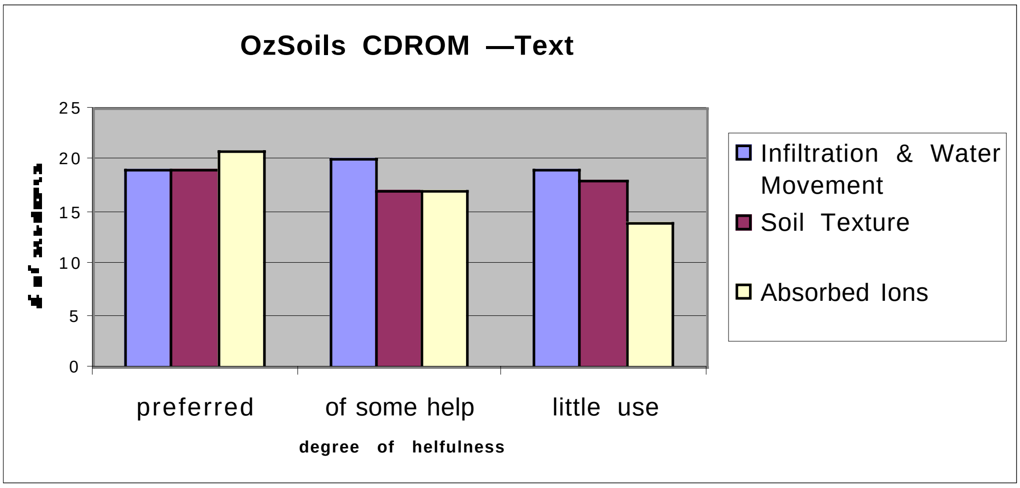

Figure 6.3. Student perceptions of the usefulness of the Oz Soils text to their learning.

Students who did not use the Oz Soils CD-ROM in preparation for practical classes increased over the period of the research. While only 13% of students did not access the CD in preparation for the first practical class, for the second the percentage had increased to 28% and maintained at 29% by practical four. At least 16% of the students had decided that the resource was not useful to their learning strategies. Student interaction with the Oz Soils CD-ROM varied with most students using the CD only once for less than 30 minutes. The intent of viewing the multimedia resource was to get a quick overview for the content prior to doing the practical class. As one student articulated during the focus group discussions:

> *"When I first started the subject I didn't know anything about soils, I used Oz Soils CD-ROM a lot to get me up to scratch with what's happening but now I've kind of toned back on it because I think I've got a bit of grasp on the subject."*

The Absorbed Ions module deals with abstract concepts of cation exchange capacity of soils. The graphics on the Oz Soils CD-ROM provide animations of the process of ion exchange, variable charges, and isomorphous substitution. The students who accessed the Oz Soils CD-ROM rated the animations as moderately useful to their learning, with 41% of the students unable to match the correct concept to the animation provided.

In the Soil Structure module, where the information, graphics and animations related more directly to the real world rather than the abstract, students were very successful in identifying the concept provided by the illustration. They also rated the graphics as being useful to their learning.

2. *How useful do students perceive the CD-ROM to be in their learning?*

Students in Soils 211 take a WebCT administered post-test within three-days following their practical class. It is an open book test and they may use any resource to assist in completing the questions. Less than half the students used the Oz Soils CD-ROM to support their study in preparation for taking the practical class post-tests. The following information was gathered from the students at the same time as they completed the assessment activity via a WebCT questionnaire.

A 'transfer task' was incorporated into the practical post-test. This task required the students to apply knowledge that they have been taught during the practical to soil context. For many students this task became quite daunting and was not received as an 'appropriate' question.

> *M: " Ok, so that was always the humdinger."*
> *F: "Always the hardest one."*
> *M: " I was pretty bewildered because it was just, I don't know, I just sort of found that I'd be answering the other 5 questions quite easily, then there's this big quantum leap…"*
> *M: "I couldn't find any indication on how to get the answers that they wanted in the table, like I couldn't find any information on how I might calculate what I needed to calculate to answer the question from the information given in the table…"*
> *F: " There was no way, like, we don't know how to approach those sort of questions because we don't get shown an example in lectures or anything like that and there's no examples in the study guide of how to approach that sort of question."*

The self-assessment questions on the Oz Soils CD-ROM were popular as a learning resource prior to taking the post-test. However, it was a study strategy used by less than half the students. In each module, the frequency of use varied quite considerably. Such results would suggest that scaffolding on the CD-ROM was not a significant support tool for most of the students.

Students were asked to rate the usefulness of all the resources they had available to them as part of the Soils 211 unit. Eleven resources were identified, with students being asked to rate them from 1 to 11 according to the use they made of them. Students were asked to make their decision following their assessment task after each practical class. They consistently rated the resources listed in Table 6.5, as being most useful. The responses to this question indicated that some students tried to make a definite point about the usefulness of study materials, by not giving a priority rating, but instead rating some activities as a one or two, then rating others as an 11. Several students indicated that all the resources rated at a 5 or 6–mediocre. Further analysis is required before a relationship of individual student success can be made to particular learning resources.

The students rated other resources as less useful (eg. Library, on-line questions, field-work, bulletin board, and self study questions in the printed study guide). Thus while students felt the CD-ROM was not as useful as the printed materials provided by the lecturers, they did rate it more highly than other resources available to them.

Focus group discussions suggested that overall the students believed that having such a full range of resources to choose from was beneficial. Most of the students took advantage of several of the options. No study resource was viewed as sufficient by itself.

> *Female: "Yeah, like you know they (Soils 211 teaching staff) make the effort. They're trying to make it easier for you to learn and how there's different ways, like they realise that you learn differently, like you have the lectures and you might have your study guide and you also have your practical and you have your WebCT as well, and Oz Soils and somewhere, hopefully, you're going to find something that works for you."*

3. *What evidence is there of transfer effects from individual study of the CD-ROM to laboratory tasks?*

Students used the CD-ROM as a resource-based learning strategy for Soils 211. Students who used the Oz Soils CD-ROM indicated that it did provide some information relevant to the their preparation for laboratory work. Students who used the Oz Soils CD-ROM in preparation for practical class indicated that they used the resource for a variety of reasons.

Results from this survey illustrate that from the

Table 6.4. Use of Oz Soils CD-ROM to support preparation for practical class post-tests.

Use of Oz Soils CD-ROM on their first try of WebCT administered practical post-test	P2 N=61	P3 N=62	P4 N=55
Graphics and text *before*	19 (31%)	21 (34%)	19 (35%)
Graphics and text *while*	15 (25%)	20 (32%)	25 (45%)
Multiple choice *before*	17 (28%)	26 (42%)	19 (35%)
Multiple choice *while*	10 (16%)	16 (26%)	12 (22%)

Table 6.5. Student perceptions of usefulness of learning resources.

Resource	Prac 2 N=61	Prac 3 N=61	Prac 4 N=55
Practical workbook	47 (77%)	38 (61%)	36 (65%)
Printed Study Guide	37 (61%)	30 (48%)	37 (67%)
Lectures	26 (43%)	28 (45%)	34 (62%)
CD-ROM 8. Multiple choice questions 9. Graphics & animation 10. Text	 25 (36%) 20 (31%) 19 (31%)	 21 (34%) 21(34%) 19 (31%)	 17 (31%) 17 (31%) 21 (38%)

Table 6.6. Support provided by scaffolding on Oz Soils CD-ROM.

Support provided	Prac 1	Prac 2	Prac 4
Information not in workbook	43%	26%	58%
Demonstrated practical procedures	20%	30%	44%
Supported prac class prep	46%	23%	56%
Provide self-test activities	48%	28%	75%

wide range of scaffold resources, the CD provides some structure for individual students. It would also suggest however, that there is significant variation in the usefulness to students and greater consistency between modules is required. Consideration needs to be given to the extent to which the individual animations, graphics and multiple choice questions are structured and linked with other support material

Students found the self-study activities the most useful of the strategies. However, as one student articulated in the focus group session, insufficient consideration has been given to the scaffolding of the feedback.

> *M: "I go through and find the right answer, because the feedback from the correct answer has explanations why the other ones are incorrect anyway generally."*
> *F: "If it's a model choice one but if it's a calculation one, you're stumped so I give up."*
> *F: "No one knows. Like you have one number you put in, you have no marks for your working, you don't understand where you've gone wrong. If you have got it wrong, so work solutions that they give out to show you how to do it and everyone tries but they don't understand where to put the numbers in the actual formula. They don't know how to convert it or don't know whether they're making, like, one mistake or many mistakes.*

In the post-test activity, the transfer task was followed by a reflective question used to evaluate students' perception of the level of difficulty they experienced in being asked to apply key concepts from each practical class. As indicated above, students found the transfer question difficult. Figures 6.4, 6.5 and 6.6 illustrate their perceptions plotted against their success in completing the activity.

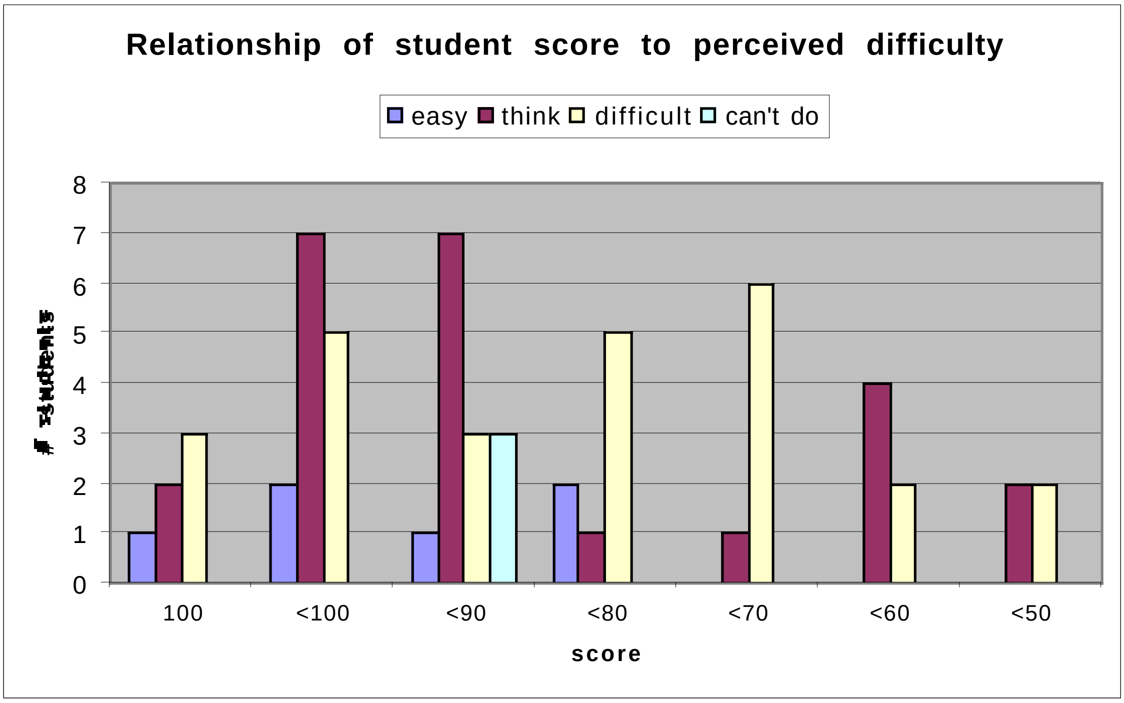

Figure 6.4. Student perceptions of the difficulty of the post-work transfer task question as a function of the score for the question, for the second practical class (Soil Phase Relations).

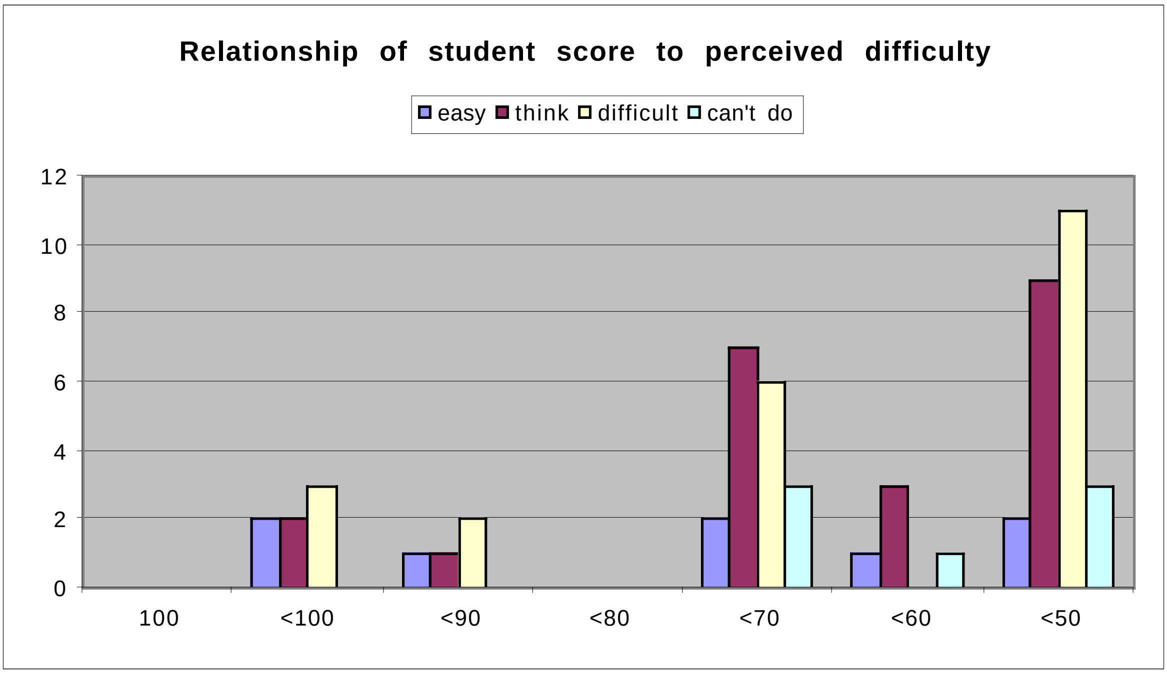

Figure 6.5. Student perceptions of the difficulty of the post-work transfer task question as a function of the score for the question, for the third practical class (Soil Texture).

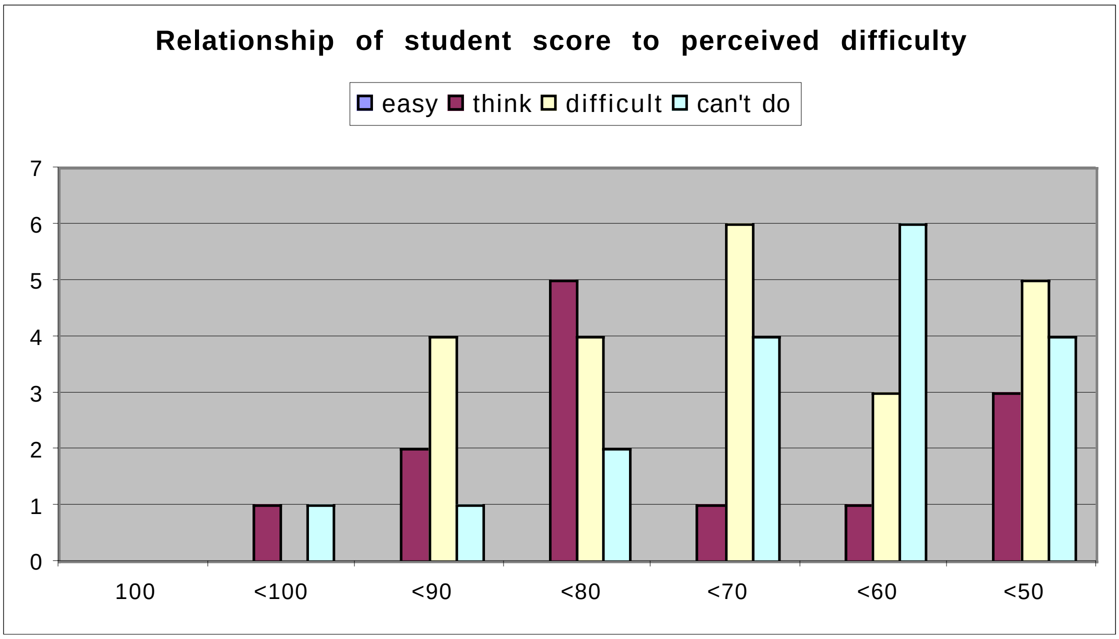

Figure 6.6. Student perceptions of the difficulty of the post-work transfer task question as a function of the score for the question, for the fourth practical class (Soil Chemistry).

Most students achieved a score greater than 50% for the transfer task question, although many found it difficult or felt that they could not do it. There did not appear to be a strong relationship between students' success at the task and their perception of its difficulty, and disturbingly there were a number of students who scored poorly (<50%), yet did not perceive the task as difficult. This mismatch between student perception and test scores warrants further investigation.

4. *What evidence is there in bulletin board discussion of understanding the key concepts?*

The Bulletin Board (BB) through WebCT was a useful item to a small number of the students, however it was not used widely. Twelve students rated the BB highly indicating that it was a useful tool to look back through previous discussions when they needed answers to their post-test activity. Discussions took the general form of a student asking for clarification on an issue, another student supporting this query by also indicating the need for clarification, and finally the lecturer offering some advice on how to achieve an understanding of the issue. Students would subsequently not pursue further discussion on this issue on the BB. We believe that we have a cohort of second year science students which will still need to develop their discussion skills using a format such as a BB. Additionally, they are still struggling to come to terms with the language of a subject new to them, such as soil science, and therefore may feel less confident in discussing issues.

5. *On the basis of the evaluation of the student learning and transfer, what recommendations can be made to enable integration of the CD-ROM resource into a tertiary study unit to foster independent learning?*

Data familiarisation and analysis, at this early stage, has only delivered some indications of student learning behaviour in relation to the CD-ROM use. A more detailed and more rigorous data analysis is necessary to make recommendations to achieve improvements in student learning. Following is a preliminary list of items, some of which may be included in the final recommendations.

- Integrate the CD-ROM more directly with the practical workbook tasks.
- Ensure that students understand the relationship of the CD-ROM to other resources.
- Provide staged feedback for all multiple choice questions on the Oz Soils CD-ROM.
- Review the images used to illustrate concepts to find more relevant options where needed.

The main implication for our teaching which we see resulting from this evaluation is to have a good look at all our teaching resources and to improve linkages between the different components. Students should not perceive the multimedia material as an additional study resource but as an essential part of their learning opportunities. What we also have to realise is that highly academically skilled students will have no problems to learn in any given environment but this is not true for the majority of our student cohort. We have to match learning opportunities better with the level of motivation, skill, and prior knowledge of our particular student cohort. This could mean that we have to make it very explicit to the students how and when to make use of the multimedia resources in their learning. We will also expand our interactive question database to allow students more opportunities of self evaluation. For our students, we have to associate a small percentage of the course grade with this formative assessment activity to sufficiently entice them to undertake it in the first instance. Obviously, it is a much easier task to foster independent learning in highly academically skilled students.

3. Reflections

In the context of diminishing resources at universities, rigorous evaluations of technology-based learning tools costly, both in terms of the required academic time investment and the required additional resources to appropriately conduct and analyse questionnaires, surveys, interviews, etc. Currently university teachers are not rewarded if they engage in such rigorous evaluation activities and university management has generally no structure in place to support such activities. One issue which was of great value to the project mentees was the introduction to a large range of evaluation instruments and the subsequent discussion on their merits. The mentees believe that, in particular academics in the physical sciences would benefit from better dissemination of the availability of a wide range of evaluation instruments and their accepted use according to current educational theory. Physical scientists come from quite a different background in conducting research and require considerable familiarisation with educational research techniques. To the mentees of this project, the most valuable part of the resources available was the mentor-mentee arrangement, in particular with the advantage of this being undertaken in the one physical location which allowed for frequent face-to-face meetings.

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