# Chapter 13. You Can Lead a Student to Water, but Can You Make Them Think?

## An Ocean in the Classroom: an Evaluation of a Situated Learning Environment

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***Abstract***

*A virtual situation developed as a CD-ROM for marine science learning, 'An Ocean in the Classroom' was developed to simulate a marine sampling regime. Students were asked to participate as the scientists in the process, choosing the most appropriate transect method for the species being sampled. The CD-ROM was designed and developed in 1998 and revised in 1999 after piloting with the student group.*

*An evaluation study was conducted as part of a Committee for University Teaching and Staff Development (CUTSD) funded evaluation project, Staff Development in Evaluation of Technology-based Teaching Development Projects: An Action Inquiry Approach. The CD-ROM development was also funded by CUTSD and designed and developed by the writer of this paper in conjunction with the teaching staff.*

*The virtual situation evaluated in this study simulates a marine sampling process which is used to form part of an assessable activity in a third-year undergraduate and postgraduate Marine Biology subject. The results of the evaluation are provided as evidence that the resource enables students to address the learning outcomes for the assessment task. Additionally, it is suggested that students also achieve a number of indirect learning gains as a result of using the resource. I describe ways in which this resource can provide authentic and meaningful activity that engages the learner and fosters a sense of ownership of the knowledge constructed. The skills the learner acquires are then transferred beyond the immediate teaching and learning situation to activities where knowledge of practical methods and techniques are required.*

*I also propose the need to move beyond a content-focused curriculum where students are presented with discipline content before they have the concrete experience with which to interpret the information. I suggest the need to engage learners in developing the practitioner skills of the discipline earlier in their scientific career as a means of preparing students for scientific inquiry.*

## 1. Background and Context

A CD-ROM resource 'An Ocean in the Classroom' was developed to address a gap in discipline specific skills and knowledge required by Marine Science graduates. Major field-based research is prohibitively time consuming and expensive to be undertaken by students in many marine science courses. This frequently results in marine science graduates and research students lacking the knowledge and conceptual understanding of problem solving in practical fieldwork necessary for postgraduate research and employment. The CD-ROM innovation being evaluated in this paper is used in a James Cook University third-year undergraduate and postgraduate subject, Marine Conservation Biology.

### *1.1 The Learning Problem*

Prior to development of the CD-ROM, students were required to complete an assessment task where they analysed a data set and presented their findings in standard scientific report format, comparing the performance of different sampling techniques for common and rare species.

During the marking of the assessment task teaching staff noticed that the majority of students were able to arrive at the correct quantitative results, produce graphs and complete a scientific report, but made little or no attempt to relate what they found to what the animals in question were actually doing. Since Ecology uses statistical methods to interpret behaviour in the field, a simple quantitative answer is insufficient. Students were unable to move beyond the purely quantitative in two ways. They were unable to relate their findings to the different methods they used and they were also unable to interpret their findings in terms of the species' ecology and/or behaviour.

### 1.2 The Learning Solution

The assessment task attempted to integrate content with practical processes (fieldwork and laboratory) but failed to do so due to financial and legal considerations which prohibited taking more than 100 students on a marine science research trip. The teaching staff and the educational designer felt that a simulation of the practical aspects of the process would provide the solution, giving the students an insight into designing and implementing an appropriate sampling regime, for species of different abundances. A CD-ROM resource was designed and developed to model the data collection process for sampling three species of fish, one common and two rare, with differing distributions.

It was hoped that integrating the CD-ROM as a learning activity leading up to the assignment would enable students to:

- Gain an insight into designing and conducting a marine sampling regime.
- Choose the best (most cost effective) method for sampling each species.
- Appreciate that different techniques are required when sampling rare species, by performing a sampling process for 3 species of fish – transect method.
- Critically interpret and relate their quantitative results to what they saw in the field. That is, explain the quantitative results in terms of qualitative observations.

An authentic and situated learning environment was created which was informed by the constructivist theories of Laurillard (1993) and Jonnassen, Mayes, & McAleese (1993) and guided by the analysis and design phase of the Alexander and Hedberg (1994), and Bain (1999) framework. We felt that a simulation of marine fieldwork would be authentic, engaging students in the process of data collection as part of the normal practice of the community (Jonassen, 1995). Students would also have the opportunity to observe the difficulties associated with collecting data on rare species, along with an insight into the species distribution. As a result of using the CD-ROM, it was hoped that students would be better equipped to interpret the results of their data analysis.

The CD-ROM placed students in the role of a marine scientist. This enabled students to experience the sort of problem solving that is an integral part of conducting marine field research, where they could also learn from their experience of being in the field. The CD-ROM simulates the data collection process, and enables the students to:

- Use a fish identification library to identify the target fish species (Appendix 13.1a:Fish Identification Library)
- Use a recording slate for counting fish and a clock for timing transects (the same tools that you would use if you were in the field) to trial sampling transects of three different lengths: 10m, 50m and 100m, and record the number of individuals they see of each species and the time it takes for them to complete each transect. (Appendix 13.1b:Visual Transect Recording Slate)
- After data collection, a 'Finished' button is clicked and the data is automatically output onto a floppy disk as a text file.

Using the data each student collects, a class data set is generated for the three species with 10 replicate transects for each of the three transect sizes. This ensures there is a sufficient amount of data from which to analyse results in the follow-up assignment, *a pilot study report*. The report follows the abstract, introduction, methods, results and discussion and references format.

In developing the report students are asked to:

- Calculate the optimum cost effective method for sampling the target species, and to
- Assess the abundance of common and rare damselfishes by examining the relationship between population density and our ability to detect adverse changes in the population. They should also consider the relative advantages of increasing the sample unit size and the number of replicate samples needed to detect a decline in density of a specified magnitude.

- Explain their results in terms of:
  - their own quantitative findings,
  - the literature, and
  - the qualitative observations they made during the collection of the data.

Some early testing of the resource was conducted to determine the effectiveness of the interface design and the functionality of the navigation used. This was conducted during trialling in late 1999. The instrument used was an adaptation of Reeves' (1992) fourteen pedagogical dimensions of interactive learning systems. As a result of this evaluation a number of changes were made to the interface and description of the activity.

## 2. Introduction

The remainder of this paper is focused on the evaluation of the CD-ROM resource. The evaluation aspects of the project were heavily influenced by the Alexander & Hedberg (1994), Bain (1999) framework as a learner-centered tool for describing the evaluation inherent in the design, development and the implementation of the innovation within the teaching situation.

### *2.1 Evaluation Plan*

The evaluation plan examined:

#### Direct Learning gains

**Achievement of desired learning outcomes**

- Were the students better able to understand how the sampling effort and reliability of estimates changes as they sampled rare species?
- Could they apply a simple technique for determining the best combination of transect size and number to assess patterns of change in the density of rare species?
- Did they interpret and discuss their results as a consequence of their engagement in the sampling process?

**Development of student learning strategies** (developed when students participated as 'scientists' in the research process):

- Were they better able to understand what constitutes marine research?
- Could they appreciate the difficulties associated with conducting marine sampling regimes?
- Were they better equipped to plan a sampling regime for their own research?

#### Indirect Learning gains

- Were there gains in technological skills amongst students and staff?
- Did the knowledge or skills gained transfer to other situations?
- Are there likely to be changes in teaching practice as a result of the innovation?

### *2.2 Data information sources*

Data was collected by:

- A survey (Appendix 13.2a) assessing the students' level of technical skill and ability prior to subject commencement.
- Observations (Appendix 13.2b) of the CD-ROM in use by students to test functionality.
- An online survey form (Appendix 13.2c) with ranked and descriptive answers - direct and indirect learning gains.
- Student Interviews (Appendix 13.2d) – expansion of the questions asked in the online survey for a small focus group of students (who had completed the online survey).
- Lecturer Interviews (Appendix 13.2e) – did the CD-ROM work as intended in meeting the design goals – were there any areas of concern? Is there anything you would do differently in your teaching as a result of developing this resource?

## 3. Results

### *3.1 Development Phase*

Results from this stage of evaluation are outlined below.

#### The pre-subject survey:

In developing a technical solution we were aware of the need for this to be as intuitive as possible. To achieve this I designed a simple-to-use interface that did not place further cognitive load on the student as they used the CD-ROM. Reeves (1992) and Hedberg *et al.* (1993) advise that when developing an interactive solution, the multitude of media representations along with the input and path choices can confuse a learner and reduce the effectiveness of the solution. For this reason, and to ensure that we did not place students with low technical skill ability at a disadvantage, a pre-subject survey and observation of the CD-ROM in use by the student was conducted.

110 third-year undergraduate and postgraduate Marine Conservation Biology students were asked to complete the pre-skills survey/questionnaire to assess their level of confidence, skill and experience in using interactive multimedia and web communication resources. This survey was carried out to determine whether the students were hindered by low technical abilities.

110 students completed the pre-subject survey. The results showed that:

- 51 percent of students used and were familiar with interactive software
- 64 percent of students used and were highly familiar with email
- 63 percent of students were unfamiliar with Web discussion forums
- 47 percent of students considered themselves highly familiar with searching the Web.
- 56 percent of students considered themselves highly familiar with the use of word processing software.
- 54 percent of students considered themselves familiar with spreadsheet software.

The pre-subject survey provided evidence that the students involved rated themselves as having generally high information literacy levels, as it relates to the use of ICT resources (Information and Communications Technology), and reasonably high levels of IT literacy. This was not unexpected and could relate to the nature of the scientific software that students must use if they are to statistically analyse data. Scientific software, particularly that used for modeling and simulation, finds its roots in DOS based applications and is often not an 'easy to use' tool. Therefore, students must learn how to use the software and in so doing they acquire reasonably advanced software skills. This along with the increasing use of ICT (Information and Communications Technology) resources has made this type of technical skill a base requirement for students. This in turn has required institutions to take a closer look at the services they have in place to support students using these types of resources.

## The student observations:

The second phase of data collection concentrated on whether the CD-ROM worked as intended in the teaching situation. There were few technical problems as the CD-ROM had been piloted the year before. However, a number of functional and instructional issues emerged:

***Navigation:***
**Interface** – insufficient instruction. It was noted that some students, particularly mature age and international students, who had no experience using a CD-ROM previously, did have some problems with the navigation. Once they received a small amount of instruction they were able to complete the activity in the allocated time.

***Functionality:***
**Data sheets** – frustration. Students expressed frustration at having to enter data on the recording slate every time they began a sample set (though this is exactly how it would happen in the field).

**Video** – too small. Students indicated that the video was too small for definitive identification of one of the target species.

***Instructional Process:***
**Feedback** – am I right? Some students felt that receiving feedback about the identifications as they were conducted was necessary for them to know if they were targeting the correct species.

> *Am I counting the right species and should I see this many fish in one transect?" and "I am not sure if I am counting the fish right – how would I know?*

The student observations highlighted a number of difficulties relating to the functionality of the interface. Some students who had rated themselves as being familiar or highly familiar with interactive software expressed frustration at having to enter detail on screen. However, the simulation activity was designed to replicate exactly how a marine scientist in the field conducted the process, and when a scientist enters details at the beginning of a measurement activity they will document the date and time and other specifics each time they begin another transect. We felt that this component could be automated but that students may not then appreciate the need to process this detail in the same way in which they would in the field.

Another difficulty emerged when technical constraints in laboratory situations forced the need to provide smaller-scale video than that which was originally intended. Students therefore had difficulty in targeting the correct species. An upgrade to the computers and advances with video software and playback ability mean that we can re-work the CD-ROM to allow full screen (or close to it) video. We are also intending to make the CD-ROM available to students as a self-paced learning resource rather than using it in a teacher directed computer laboratory situation with timeline constraints.

Results from this stage of evaluation indicate that some mature age students had problems with the navigation structure. It is clear that if we are to adopt and use this type of technology, then we should also ensure that the students who will be using it have the IT skills required to do so. Changes that will be made to the CD-ROM will ensure that less instruction is required at the outset of using the resource. However, this is only one aspect of the problem. Knowing and understanding the levels of IT literacy amongst students prior to their engagement in an IT task is equally important. The recommendations from a research report conducted for the Department of Education, Training and Youth Affairs (DETYA) by Oliver and Towers (2000), 'ICT (Information and Communications Technologies) Access and Literacy of Tertiary Students in Australia', shed some further light on IT skills and literacy levels and the institutional responsibilities relating to them. The report recommends that institutions should ensure that:

- all students have equal access to computers.
- the ICT literacy levels of students' should be established at course commencement.
- adequate support for students attainment of the requisite skills is provided.
- they monitor the levels of ICT literacy amongst students.

Subsequent to the introduction of this resource, JCU has introduced a student IT skills audit. This will allow a student to assess their level of skill in a range of areas and where their skill levels are low, receive a tailored program for IT skills development. This along with some simplification to the navigation will assist students whose IT skill levels may obstruct their initial use of this resource.

There were also problems with species identification, with students saying that they required some feedback if they were to know whether they were in fact targeting the correct species. Again, there was some discussion about the need to emulate as closely as possible the realities of data collection, of which this is one. However, a solution presents itself in guiding the student through the activity. This is the basic premise of much of constructivist thinking, the goal of which is to guide students so that they begin to think and act like the practitioners of the discipline. (Brown, 1989). We have decided there is a need to do this with the resource, to create a test base with a comparison table for results, prior to asking the students to begin their data collection for real.

### *Implementation Phase:*

#### Web Survey:

Of the 110 students who were asked to complete an online survey form about the CD-ROM, 60 responded.

The resulting data provided some insight into how well the resource addressed the direct and indirect learning gains as outlined earlier:

- 80 percent of the students indicated that the CD-ROM greatly assisted their understanding of how the reliability of estimates of abundance changed when examining rarer species.
- 78 percent of the students indicated that the CD-ROM greatly assisted their understanding of what sampling effort was required to achieve reliable estimates when sampling rare species.
- 61 percent of the students indicated that the CD-ROM greatly assisted their understanding of how the distribution of rare species (eg. clumped versus regularly distributed species) affects the choice of the most cost-effective (t) sampling unit size.
- 68 percent of the students indicated that the CD-ROM greatly assisted their understanding of the potential problems in conducting marine research.
- 64 percent of the students indicated that the CD-ROM greatly assisted their understanding of how they might plan a sampling regime for their own research.
- 42 percent indicated the CD-ROM was some motivation to them to conduct their own research in the future.
- 78 percent indicated the CD-ROM was a much improved learning experience compared with other learning experiences they have had.

Students were then asked to describe what it was about the CD-ROM that most helped with their understanding. From the students' descriptive answers, clear themes emerged.

## Emerging Themes

**The representation**
One group of students saw the resource as providing an observer's view of how a sampling regime would be conducted in marine science. These students focused on the visual aspect of the resource.

> *The visual aspect I suppose. To actually SEE the distributions of the fish in the flesh and not get a piece of paper composed by someone else dictating where THEY saw individuals along the transects.*

With this group of students, it seemed that the novelty value of using the resource prevented them from progressing beyond this *visual representation* of a marine sampling process. Their descriptions were clearly oriented around their observer status and not their practitioner role.

**The reality**
The majority of students commented on the importance they felt in actually being able to do the sampling themselves rather than receiving a set of data points.

> *The CD-ROM gave me a good feel for visual transect sampling techniques and the type of information that I might expect using them. It also revealed their limitations but was a great insight into the amount of work required in data collection, especially for rarer species.*

Their engagement in the 'actual' sampling process placed them in the role of scientist where they were better able to appreciate why the technique was chosen, and the practicalities of performing the technique. Some students indicated that it went further than this, and provided a means of reinforcing concepts and theories presented in the literature.

> *Because you had to "swim" them and count, it was a lot more real then just being given the data. You could see how rare species abundance varied- none or few on some transects, more on others etc... Thus you knew as you read the papers that rare species would have more variable counts, need bigger transects to sample more of them, and also more replicates. It reinforced the information from the papers we read.*

Others stated that information from quantitative data is often more clearly understood when you are involved in the process that leads to the development of the data set, such as determining the clumping of species.

> *The simulation helped with my understanding of clumping of fish species. This type of understanding is difficult to obtain by just looking at data.*

**The difficulties**
Many students extended the notion of engagement in the real process as a means of helping them understand the difficulties involved in conducting marine sampling and the amount of sampling effort involved.

> *The CD-ROM helped out most in understanding the difficulty associated with visual transects, especially when targeting rare species or animals with clumped distributions. Additionally, the time required to lay out transects and remain within constraints so the study is feasible.*

One student commented on the multi-tasking aspect of data collection, the act of just having to observe, identify and record at the same time.

> *The difficulty in identification and recording at the same time was most evident. I have only done a real transect once so it was a good illustration of a method with which I am minimally familiar.*

**The assignment/analysis was more beneficial**
A number of students indicated that the subsequent analysis conducted as part of the assignment was more beneficial to their understanding than the resource.

> *Just the fact that we had to crunch numbers, generate the graphs, and then loosely interpret them gave a better knowledge of how data sets turned into conclusions. It was not the CD-ROM, we could have done almost (but perhaps not quite) as well just by working on sets of raw data, sorry guys. Counting the fish on the*

*computer is cool, but the program is just not that enlightening as to the science aspect.*

However, within this group, students indicated that the clumping and patchy distribution of the species was more evident when observed in the resource than in data.

*It wasn't the CD-ROM per se...more the analysis of the data. The patchiness of the rare species was more evident when seeing it on video than just imagining it or seeing it written in a diagram.*

One student complained because they were not given the opportunity to design the experiment themselves, and indicated that a better understanding could be reached if this aspect of a research study had been incorporated too.

*Because we had no involvement with the actual design of the experiment, only the data collection, it did not increase my understanding of planning my own sampling regime.*

I spoke with the lecturers about this issue and their response was,

*The real purpose of the exercise, the simulation and subsequent assignment, was to examine the performance of various sampling techniques for common and rare species, with in a simulated pilot research study. So that when they come to do the environmental impact assessment (EIA), later in the subject, they had the pre-requisite knowledge in order to design their own project.*

### Student Interviews:

A series of follow-up student interviews were conducted with 10 students who were randomly selected from those who completed the online survey. The themes that emerged from the online survey helped to shape the questions for the interview phase. I asked the students to describe their experience of learning from the CD-ROM, how it helped with the follow-up assignment and their prior levels of experience in conducting marine sampling regimes. They were also asked to describe ways in which the CD might assist with other research activities.

**The CD as a learning experience:**
Students alluded to the concrete experience, the importance of being able to do the process, instead of being presented with facts.

*It's the hands on stuff, instead of somebody standing in front of you in a lecture and telling you all the facts and you just sit there and get very bored. The hands on where you learn through doing it yourself. You grasp stuff more that way or I at least do. Like if you dissect something you understand the structure more than if you just read it in a book cause your actually doing more hands on. The CD was one of the more interesting parts of the subject.*

Another student commented on the linking of the process to the content of the discipline

*The fact that you actually got to experience the sampling, and it provided a very strong visual link with the learned information.*

It was clear that, particularly for the students who had not collected marine data before, the experience of being placed in the role of practitioner was a useful one for them. It enabled them to trial a process they would not normally have engaged in, and it meant they were better able to understand the reasons for choosing that particular approach to sampling.

*It was really helpful in seeing how the transects were carried out and the difficulties when you weren't sure what species it was and it helped to build up our confidence in our ability to identify fish. As a teaching tool it helped a lot because we could relate numbers it gave us with the frequency of the fish and rareness, so how often you would see it in a transect. I haven't scuba dived much so I wasn't sure about what I should see or what the results should say. So if someone just said to me what the frequency of seeing that fish in the transect was I wouldn't understand what it meant but getting to do it for myself made it more realistic.*

The student responses at this stage of evaluation reinforced their need to be engaged in the activities of the discipline as a means of authenticating the experience for better understanding.

A number of students saw this simulation as important to them, as the collection of that amount of data would in real terms take a long time, but with the simulation, they were able to conduct the sampling themselves in a one-hour computer tutorial.

> *We found out how hard it was to sample species out in the natural environment………Going through that and understanding the frustration that goes behind field study in marine biology and the extreme concentration in trying to figure it out and how long it really takes. I think using the CD in the class was a good experience, not that it was incredibly fun but just that it was a good experience to see how real fieldwork works and the frustrations and stuff.*

**The CD-ROM as a means of increasing understanding for the subsequent assignment:**

The students' response to this question further reinforced the strength of the resource for building an understanding of data collection techniques, and providing the basis for students to describe why they have reached that particular understanding.

> *………… one of the species was more dispersed in the environment and that's why you have to use longer transects …… when you have just numbers on a page you don't quite have that same appreciation whereas two of the species were similar numbers but one was a little bit lower numbers, so it was the clumping. So I guess that was the biggest thing and that was the climax question on the assignment was to realise that they were more dispersed in the environment and someone can tell you that but until you actually see it you don't understand.*

Again, it was the students who had not collected marine data before who seemed to gain the most from using the resource.

> *I don't really think it helped with the assignment at all. The assignment was more about doing the equations to find out whether it was precise or accurate which I had done before……..that was the main point of the assignment so you could have done it without counting the fish, you could have given us a whole sheet of data. I guess it gave an idea to people who didn't have any idea how to do fish transects what a fish transect was.*

Most students interviewed indicated an increased feeling of ownership of the data because they had collected it themselves. This seemed to provide additional motivation for completion of the related assessment task because they were more interested in viewing the results of their first experience collecting 'real' data.

> *The CD was part of the assignment. It was about counting the rare fish that you saw so I think it helped to see what sampling was like and to see how difficult it would be to sample rare fish compared to giving me a table and saying 'these are the results'. I had a little bit more say in what the data set was, so I was more interested and more involved rather than the classes were they give you a data set, and say 'tell me what you think about rare fish'.*

## Lecturer Interviews

I asked the lecturers involved in using the CD-ROM in the teaching situation to describe how it assisted students.

**Sampling opportunity**

Lecturers described the resource as being extremely useful in the design and implementation of a marine research project. In particular, it was described as having assisted the students in their appreciation of the difficulties associated with the sampling of rare species. One lecturer described its' usefulness for students who had not experienced marine sampling before. He also commented that one or two students indicating that they did not need to do this tutorial as they had done marine sampling using transects before.

> *I thought students with some field work experience gained less than students with no fieldwork experience. They thought that the CD-ROM was unnecessary for them, so they missed its' relevance and did not critically analyse the data in the assignment well, they got the crude message but were unable to tease out the detailed interpretation of their results. Part of this problem though was caused by the way in which we conducted the tutorial,*

*it was rushed. When we have improved the CD we will give them to students so they can do the exercise in a more relaxed atmosphere and have time to make qualitative observations rather than just collect the raw data.*

**The CD-ROM as a means of increasing understanding for the subsequent assignment:**
On completion of the associated assignment, the Lecturers had the following comments to make,

*The CD helped students explain their results, with reference to the literature and in terms of what they observed when collecting the data. The literature isn't always right or applicable, so it is vital to compare what you might expect to what you actually see. But I was disappointed that more students did not ask 'what do I think is happening?'. I had hoped that simulating the data collection would help them absorb the visual distribution information while counting and then in the assignment they would be able to discuss this, but I am not sure that we actually achieved this. They still missed the significance of relating their statistical results to what they actually saw when collecting the data.*

The lecturers were disappointed that the students were not better prepared to interpret their results in light of what they saw during the data collection. However, it seems clear from the student responses to the questions asked in the survey and interview phases, that the patchy distribution and clumping of species is a message that they understood as a result of their engagement in the virtual situation. The students said:

- *you could see how rare species abundance varied*
- *it was clear that rarer species may not always be observed in small transects if populations are somewhat clumped*
- *helped me to better understand sampling rare species and how the abundance changed from common species to rare species*
- *helped with my understanding of clumping of fish species……difficult to obtain by just looking at data*
- *triggers thoughts about cryptic species under rocks, clumping, what fish you count*
- *the abundance differences observed for the three transect lengths*
- *targeting rare species with clumped distributions*
- *the patchiness of the rare species was more evident when seeing it on the cd rom*

If this was indeed understood by students then why in the subsequent written assignment were they unable to describe this observation in reference to what the literature said and what their results indicated? The answer may well be found in the way in which we teach science.

## 4. Discussion

### *4.1 The Teaching of Science*

In science, there are a number of factors that frequently limit students' exposure to the practical methods of the discipline. The first problem is the increasing cost of the fieldwork experience, particularly for large groups of students operating in a physically restrictive environment. The labour intensive nature of marine fieldwork makes collecting sufficient amounts of data, to be statistically robust, extremely difficult. Secondly, there is the issue of liability which is of particular concern when SCUBA diving, which potentially involves many relatively inexperienced students. Institutions are also under pressure from employers to ensure that students have the process skills of the discipline before they enter the workforce, as well as up to date content knowledge. Edelson (2000) refers to the increasing demands on the teaching time available to facilitate the teaching of content and process skills, that foster a deep conceptual understanding that students can draw on to create explanations, make predictions, and argue from evidence, this calls for the process of inquiry to be afforded a more prominent role in science teaching through authentic scientific practice. These demands on teaching time, along with the fast pace of new scientific knowledge, in part due to technological advances, produces considerable pressure on teaching staff to present new knowledge as it becomes available, as well as teach the process skills of the discipline.

The result of keeping ahead of changes in scientific knowledge and teaching the process skills that students require, often results in the need to introduce a more integrated curriculum where process and content are taught within a subject. In science teaching, attempts have been made to overcome the time factor involved in the collection of data by providing raw data sets for students to interpret. These data sets are often presented in a tutorial situation, usually from a study of a 'real' research project. Students are asked to analyse, graph and describe the results, then interpret the findings and discuss them within a written assessment situation. The teaching staff of this subject noticed that, whilst students could analyse the data, their lack of knowledge about the practical methods used placed them at considerable disadvantage when writing their assessment task. Based on their data results, the students were unable to question or recommend changes to the practical methods of the study.

## The Learning Process

The teaching of hands-on experiences for inquiry learning as presented by Jerome Bruner (1966), has been understood for many years. Kolb (1984) describes this element of teaching through experience as Concrete Experience. He explains that it should be the first phase of learning, and is followed by, reflective observation, abstract conceptualization and active experimentation. Kolb (1984) advises that completion of all four phases is required for a complete learning experience. We are informed, however, that this will not occur automatically due to students' preferred learning styles. Some students may be strong experiential learners, but require assistance in learning abstract concepts. This is in line with the theories of Piaget on the production of discovery-based skill in children. Piaget argues for the foundations of logical thinking as the integration of direct experience allowing students to manipulate objects, before they can comprehend abstract concepts or principles. It is the context within which the practical task is performed that provides meaning to the activity and enables the student to construct or deconstruct their knowledge within it (Lave, 1991). If we require students to be expert practitioners, who can analyse and interpret the concepts and principles of the discipline, then we must engage them in the practical methods of that discipline prior to presenting them with decontextualised knowledge for their interpretation. Kolb (1984) would suggest the need to include activities that encourage prior to the presentation of abstract conceptualisation and then complete the cycle with active experimentation.

The formation of assumptions from results and how they affect the physical environment is one that Connelly (1977) explores in how students defend the meaning of their claims through the process of scientific enquiry. Connelly explains that a student will tend to see the data as fact, giving rise to a knowledge claim as the main basis of their judgment unless they are engaged in the whole process of scientific inquiry. It was clear that lack of engagement in the practical processes was at the heart of the problem for students in this subject. The teaching staff explained how the students could produce graphs that indicated the correct quantitative result, but they could not adequately describe the reasons why this result was reached or the implications of the findings for that particular species or situation, in the marine environment.

## Learning in Context: the Skills of the Practitioner

The need to engage the novice in the range of skills deployed by the expert is well established (e.g., Hedberg and Alexander, 1994). Furthermore, it can be argued that this engagement should be in the form of authentic activities of the *community of practitioners,* as a method for students to reach an implicit understanding of the professional world and the tools of that world (Brown, 1989). The educational designer drew on this engagement in authentic practice as a means of placing the student as a participant rather than a remote viewer within a marine science practical situation.

These findings, along with the identification of the learning problems, reinforce the need to situate the students in the role of practitioner. Ideally this should be achieved in a real situation but where this is unfeasible a simulation can be substituted. The use of simulations as a tool for learning can provide the real experience for the aspects of discipline content where the practical experience is difficult (Corderoy, 1993). The Ocean in the Classroom CD-ROM was developed to simulate the marine data collection process for a marine science study on common and rare species, for third year undergraduate and post-graduate students of Marine Conservation

Biology. The simulation used was a series of underwater transects (measuring methods) for determining the number of any given species at a particular time within the boundaries of the transect. The student had control over the type of transect chosen and the number of replicates required to provide what they considered to be an appropriate data set for their assessment task.

The results from the web survey data indicate that a high percentage of students found that the resource was of great assistance in achieving the direct learning outcomes of the activity. They found that their understanding of sampling rare species and their ability to choose an appropriate sampling unit was greatly facilitated by the resource. It is clear that there are also some indirect learning gains resulting from use of the resource, that can be described as transferable to other research and learning situations. The students tell us that they do indeed have a better understanding of what constitutes a marine sampling regime, and they certainly have a better insight into the difficulties involved in conducting marine sampling. The high number of positive comments from students also indicates that the experience of learning from the CD resource was a positive and motivating one for them. However, on marking the subsequent assignment, the Lecturer indicated that the students could choose the best method and explain their reasons for this choice well, but that there was no significant increase in the number of students who were better able to interpret their results in light of what they saw happening in the field.

## Integrating Process and Content

Simulations are commonly used to integrate process with content, by engaging the learner in the meaningful practices of the discipline (Brown, 1989; Corderoy, 1993; Hedberg, 1994; Laurillard, 1993). Results from this evaluation reinforce the strength of integrating the process aspects of science with the content, in providing a means for student to come to a more holistic understanding of the discipline. We feel confident that the resource has achieved this goal.

Our methods of teaching place the content as the focus through a lecture situation, where ‘the facts’ of the discipline are presented to students. A tutorial type activity usually follows, where students are involved in debate and defence of particular assertions or viewpoints presented in the literature. The laboratory then introduces students to techniques that have been mastered, where precision and accuracy are paramount and testament to the existing knowledge. Students rarely, if ever, are encouraged to analyse the inadequacies of the foundations of that knowledge and so do not discover its limitations and they certainly cannot address solutions or even explore other possibilities as alternatives to that knowledge (Schwab, 1962). Assessment activities then follow which often engage the student in ‘measuring’ their results through quantitative processes, thus removing them from the realities of what is actually happening. This *hidden curriculum* teaches students the norms, values and dispositions that occur, simply by them living and coping with the institutional expectations and routines (Apple, 1979).

Furthermore, the conceptual principles of inquiry render scientific knowledge as unstable and subject to change, because research is not guided by the first principle that formed the inquiry, or further extended by new conceptual principles (Schwab, 1962). The tutorial situation can place the student in the unenviable role of contesting conceptual principles and scientific facts. In this evaluation project, the teaching staff have informed me that students are quite prepared to refute the facts that they are presented with in a tutorial situation. A well-structured tutorial provides an environment where the student can come to an understanding of what they know, through open dialogue with tutors and discussion with peers. However, when students were required to question the literature evidence in a written assignment, they seemed unable or unwilling to do so. There seems to be a tendency by the student to place a higher value on the evidence in the literature than their own evidence, even when their findings and what they are seeing refutes what they read.

An additional difficulty stems from the placing of the student in a passive role that renders them ‘silent’, for the role of student is traditionally that of knowledge recipient. With some re-engineering of curriculum, we can place students in the more active role of ‘expert’ constructing knowledge. This requires a change in the role of teacher to that of facilitator and a shift from a content focused curriculum, where the content is not presented as a *rhetoric of conclusions* but where students view the 'facts' of science as a search for meaning, concept seeking and concept forming as the main objective (Schwab, 1962). Indeed, skeptical questioning and imaginative speculation to reflect on experience have been shown to deepen knowledge (Brookfield, 1987).

### Evaluation for Quality Improvement and Change in Practice

Many CAUT-funded teaching development innovations have been criticised for lack of rigour in the evaluation processes (Alexander, 1998). If we are to improve the learning outcomes and processes we aim to achieve, then a robust investigation resulting in improvements in the teaching situation as well as the innovation must occur. I have discussed the findings from this evaluation study and the direction in which we now find ourselves, shifting from a content focused curriculum towards a learner-centred curriculum. Our goal as educators, could be the integration of the conversational framework in practice, where a learning environment engages students in a goal-action-feedback model throughout the learning process. This requires a shift towards the development of new principles to assist students in redefining the content, in ways that will lead to further inquiry and hypothesis, thus presenting and expecting *failure* as a normal part of that process. A simple shift to the presentation of a tutorial at the outset of a subject, rather than the current model of presenting content knowledge first, may assist us in moving towards a more learner-centred curriculum, that provides the opportunity for students firstly to engage in what Laurillard (1993) calls the *discursive* aspects of knowledge construction. The remaining components of the conversational model require the students' engagement in activities that allow them to *adapt* and *interact* with the discipline content. This requires the students' action in the world of the expert, the insight of the practitioner, and their discourse about their actions in this world. The last component of the Laurillard model is the *reflective*. This could be accommodated in a learning situation through the use of a reflective journal, or what Edelson (2000) describes as a *Progress Portfolio* which would be used by the learner to facilitate reflective inquiry. However, this would remain within the realm of the individual and may need some intervention within the world of the expert, to be a more powerful learning tool.

Providing the expectation that students will *fail* as they engage in learning, and that this is a normal and expected part of the learning process will provide the basis for students to contest the evidence they are presented with, and that they find through their own investigations. It will absorb them in knowledge construction and scientific inquiry that is less confrontational. It will ensure that they do not continue down the well-trodden path of hypothesis through to theory and finally to fact but see it as a process of investigation and discovery, learning how to hypothesise and critically analyse, Laurillard (1993) in her analyses of teaching and learning in a tertiary context discusses how academics are concerned with what is known of the content of their discipline rather than how it has come to be known. She extends this to mean the need to emulate everyday knowledge that is situated in the authentic activities of the discipline.

The rapid pace of scientific discovery, in part due to technological advances, presents an additional problem. The result is that institutions are frequently under considerable pressure to present new knowledge as it becomes available. In biological science at James Cook University, the results of recent research quickly find their way into the curriculum content as the lecturers teaching the discipline are also heavily engaged in research. This means that curriculum is very current and relevant and it also places the scientist in a highly respected and quite powerful position, particular where the 'facts' that are being presented to the students in lectures are indeed those of the lecturer, acquired through the hard toils of their research.

The Alexander & Hedberg, (1994); Bain, (1999) framework presents two components that form the *institutionalisation* phase of the evaluation process. The first of these is; *Impact evaluation, which refers to the robustness of the learning and its transfer beyond the immediate context of the innovation.* The results of this evaluation presents sound evidence of the students' ability to transfer the skills they learnt as part of their engagement in the activity. This is seen where the students refer to their increased ability to plan and conduct their own sampling regimes. The second component refers to *Maintenance evaluation, as the sustainability of the innovation in the context of the whole course*. I am making the assumption that *whole course* refers to the subject within which the resource is used. With modifications as a result of the evaluation this resource will continue to be used within its intended context, and there are plans to extend it to include two further modules, the first of these would be 'preparing for marine research' and a further module on 'impact assessment'. I believe there is also a need to look at how the evaluation can *extend* beyond the immediate innovation. I have in discussion addressed the need to change the way in which we teach the process of scientific inquiry and this is clearly an institutional matter, because the teaching of science is situated within the institution and bound by institutional practices that constrain the way the curriculum is entered into by students. The methods that we use to teach the process and content of science, and of any discipline, are constantly being produced and re-produced within the context of the institution.

## 5. Conclusions

The evaluations conducted indicate that the resource did indeed assist the students in gaining an insight into the design and conduct of a marine sampling regime. Furthermore, they were better able to choose the best and (most cost effective) method for sampling each species, as well as gain an experience of a particular sampling technique, which they could refer to knowledgably as practitioners in their follow-up assignment. However, the resource did not assist students in their ability to interpret and explain their quantitative results as qualitative observations when they were asked to do so in the subsequent assignment. They were however, able to point to the patchiness of species distribution during survey and interview.

In order to understand this problem, I will go back to the basis of preparing students for the process of scientific *inquiry*, and to do this, we need to examine the way in which science is taught. If we consider the core principles of scientific inquiry, as the ability to:

- formulate hypotheses
- collect and evaluate literature, placing a value judgment upon it
- gather evidence - data collection
- interpret evidence, and
- defend conclusions based on the evidence collected and what the literature describes,

then the basic ability of a scientist to question and critically analyse are at the core of these principles and yet they are the skills that our current curriculum places least value upon.

If we accept the elements of tertiary teaching and learning as presented by Laurillard's conversational framework model (1993), then we can identify the need for students to re-describe and re-define their knowledge within a 'goal-action-feedback' cycle. It is this component that a 'simulation' based resource cannot by its nature influence. This is within the realm of the teaching and learning domain as identified by Laurillard (1993) when she refers to simulations, *None of them succeed in supporting all the activities in the complete learning process, but they are the only media so far to offer interaction at the level of action in the real world, albeit a simulated one. The link between this and the student's redescription……makes them pedagogically very valuable, as long as the remaining learning activities can be covered by other means.*

In this study, the virtual situation clearly provides a valuable means of engaging students in the real practices of the discipline; it also assists the students' ability to describe sampling processes used, what they actually observe as happening and to transfer their knowledge beyond the current situation, to other research activities. It is clear that when we then expect the student to interpret and describe with reference to the literature that they seem to have problems. This situation could be improved by the student having the opportunity to present their preliminary findings for consideration and discussion by their peers. A short presentation and discussion of findings could go some way towards permiting some reflection on how the knowledge has come to be known, that is somewhat less confrontational for the students than presenting their written work for the scrutiny of experts.

The feedback from the evaluation points to the inadequacies in our current teaching and learning practices for the development of the process-level skills such as problem solving and analyses. Technology advances do indeed allow us to 'lead the student to water' by simulating the marine environment, but a simulation alone does not provide the situation that enables the student to think .

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## 7. Appendices

To conserve paper, the Appendices to this report are only available at

http://cleo.murdoch.edu.au/projects/cutsd99