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You can lead a student to water, but can you make them think? An evaluation of a situated learning environment: *An Ocean in the Classroom*

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A marine science virtual environment was developed as a CD-ROM to simulate marine sampling procedures for abundant and rare species. Students participated as scientists in the process by conducting fish counts for species of differing abundances and sampling unit sizes, calculating the most cost effective sample unit size for common and rare species, and then presenting their findings and interpretations in scientific report format.

This paper reports an evaluation of the CD-ROM as it was incorporated into an assessable activity in a third year undergraduate and postgraduate Marine Biology subject. The evaluation evidence indicated that: (a) most students were able to navigate and use the CD-ROM effectively; (b) most students experienced an improvement in their understanding of the sampling process, particularly with rare species; (c) staff confirmed that there was an improvement in students' understanding of the sampling process, including how to choose and undertake the most cost effective sampling method; but (d) this understanding did not always improve students' ability to interpret their results critically and to relate them to what they had observed in the field. These findings are discussed in terms of what is required to provide students with an authentic learning experience as marine scientists, and how the CD-ROM could be incorporated into such a learning experience in the future.

Introduction

In science, there are a number of factors that frequently limit students' exposure to the practical methods of the discipline. Factors such as the increasing cost of fieldwork experience, the time intensive nature of marine fieldwork, and the issue of legal liability, which is of particular concern when SCUBA diving. Balancing the demands of teaching practical methods as well as keeping up to date with the fast pace of new scientific knowledge often results in the need to introduce a more integrated curriculum, where process and content are taught within a subject. Such an approach increases demands on teaching time, but fosters a deeper conceptual understanding that students can draw on to create explanations, make predictions and argue from evidence (Edelson, 2000).

The learning problem

In a third year and postgraduate Marine Biology subject at James Cook University, attempts have been made to integrate the process skills in the teaching of a subject by providing 'real' research projects for students to learn from. The data sets used in the research project were presented to students in a tutorial situation where their assessment task was explained to them. They were asked to analyse, graph and describe the results, interpret the findings, and discuss them in a scientific report. On assessing the students' reports, the teaching staff noticed that although the students could analyse the data, their lack of knowledge of the practical methods used to collect the data placed them at a considerable disadvantage when discussing and interpreting their findings. Based on their data, the students were unable to question or recommend changes to the practical methods of the study. 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 species in question were actually doing. Since marine ecology frequently uses statistical methods to interpret behaviour in the field, a simple quantitative answer is often insufficient. Students were unable to move beyond the purely quantitative in two ways. They were frequently 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' behavioural ecology.

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 (the writer of this paper) felt that a simulation of the practical aspects of the process would address some of the learning problems.

The learning solution

An authentic and situated learning environment was envisaged that was informed by the constructivist theories of Laurillard (1993) and Jonassen, 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 engage students in the process of data collection as part of the normal practice of the marine science community, as recommended by Jonassen (1995).

A CD-ROM resource, *An Ocean in the Classroom*, was developed to give students an insight into designing and implementing an appropriate sampling regime for species of different abundance. It was felt that this would address the discipline specific skill gaps identified during curriculum analysis. It would also provide the context for students to use as a practical benchmark of 'own experience', through which they could interpret quantitative findings in terms of what they actually saw in the field. This in turn would ensure the students were better placed to interpret their observations and data in the context of the literature. The visual transect technique chosen for the simulation is the main method of sampling used by marine ecologists across a broad range of ecological investigations. Knowing how this technique is conducted, and its limitations, is foundational knowledge that cannot be gained by reading literature alone.

The CD-ROM resource

The CD-ROM places students in the role of a marine scientist where they can experience the kind of problem solving that is an integral part of conducting marine field research. In developing a technical solution we were aware of the need for the interface to be as intuitive as possible, to ensure that we did not place students with lower technical skills at a disadvantage, or increase the cognitive load on students by requiring them to learn how to use the interface. 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 (Reeves, 1992 and Hedberg *et al*. 1993). Therefore, the CD-ROM used a simple graphic interface that led the students to:

- A fish identification library where they can gain species information, view a photograph and video that demonstrates how the species behave in the field. When the student feels comfortable with their ability to identify the target species they return to the main menu where they can choose a transect size.

- A choice of transect sizes for sampling (10 m, 50 m and 100 m. A transect size is chosen and they are then taken to a section that simulates the transect process.

- A transect process screen with a recording slate area for data input, a video of a transect in process and a timer that records the duration of the transect. Students record the abundance of the species they view by clicking on an up arrow next to the species name, or a down arrow if they have inadvertently entered the wrong data. These simulate the tools that a scientist uses in the field. When the transect ends, and the data is collected, a 'Finished' button is clicked and the data is automatically output onto a floppy disk as a text file.

The subject context

Students taking this subject were either in their final year of undergraduate study or in their first year of postgraduate study. Many of the students spoke English as a second language, and for this reason, it was considered important to reduce the reliance on English for use of the CD-ROM. It was also felt that in general, students studying science have good skills in the use of technology, as they are exposed to technology throughout their studies and their abilities to use scientific software are relatively high. Therefore, the teachers expected few difficulties in using the CD-ROM.

The CD-ROM was presented to the students during a tutorial situation where they received some brief instruction on its use together with assignment guidelines. Students then conducted a trial run during the tutorial class, where tutors were available to provide assistance if required. The CD-ROM was made available to students to take from the class and use for collection of data for their written assignment.

Assignment requirements

In developing the report students were asked to:

- Calculate the optimum cost effective method for sampling the target species.
- Assess the abundance of common and rare fishes by examining the relationship, in terms of the accuracy and precision of density estimates, between sample unit size and species density. They were also expected to 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 they had read, and the qualitative observations they made during the collection of the data.

Students also received an assignment guidelines document that detailed:

- The problems of sampling rare species and the purpose of a pilot study. This provided the context for the students' assignments.
- The purpose of the CD-ROM in bringing the ocean to the classroom, as well as an explanation of each section of the CD-ROM with instructions on how the CD-ROM should be used.
- How to write a scientific report using the abstract, introduction, methods, results and discussion and references format.
- How to conduct calculations, present results and analyse data. For the purposes of data analysis, students were provided with a set of questions that were designed to elicit descriptive responses that they could use in the discussion section of their reports.

Using the data each student collected, a class data set was generated for the three species with 10 replicate transects for each of the three transect sizes. This ensured there was a sufficient amount of data from which to analyse results in the pilot study report. This assignment exercise was considered important within the overall subject, and carried a weighting of 30% of the coursework assessment marks for the subject.

Evaluation plan

A formative evaluation of the CD-ROM resource was conducted in late 1999, to determine the effectiveness of the interface design and the functionality of the navigation. The instrument used was an adaptation of Reeves' (1992) fourteen pedagogical dimensions of interactive learning systems. Observation of the CD-ROM in use was conducted to observe how well the navigational, functional and instructional aspects of the CD-ROM performed for the intended student audience. The results of this evaluation prompted a number of changes to be made to the CD-ROM (specifically the interface) and also to the assessment task. Though learning outcomes were not directly evaluated at this stage, the assessment task was extended and became a major component of the subjects' assessment, with closer linkages to the subject learning outcomes.

The evaluation of the improved CD-ROM and assessment task was guided by the Alexander & Hedberg (1994) and Bain (1999) framework. This was used as a learner centred tool for planning the product development and for guiding the structure of the evaluation and the implementation of the CD-ROM within the teaching situation. The evaluation was conducted as a means of ascertaining the usability of the CD-ROM as a tool for practice. This was considered an important part of the evaluation as we wanted to ensure that no technical barriers blocked a student's ability to achieve the learning outcomes. Given the amount of work that had been undertaken to develop the resource we also felt it important to find out whether the resource provided the solution to the learning problems identified and assisted the students in their achievement of the learning outcomes for the assessment task.

The usability of the CD-ROM resource

Usability was evaluated with a range of questions designed to enquire into the effectiveness of the CD-ROM while it was in use by students. The questions are outlined below:

The navigation and interface (the path through the material)

- Did the students know what to do?
- Could they choose the appropriate path through the material?
- Was it clear to the students what the navigation buttons were for?

The instructional design

- Do the students know what they are looking at and do they know what is expected of them?
- Can the students complete the task as expected?
- What barriers or problems did the students face in using the CD-ROM?
- What comments did the students make as they used the CD-ROM?

Learning outcomes

The achievement of learning outcomes (both direct and indirect learning gains) were evaluated using the following questions:

*What were the **direct** learning gains?*

- Were the students better able to understand how the sampling effort and reliability of estimates change 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?
- 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?

What were the ***indirect*** *learning gains?*

- Did the knowledge and skills gained transfer to other situations?
- Are there likely to be changes in teaching practice as a result of the innovation?

The methods used to gather data

The methods used were:

- Observations that monitored the CD-ROM in use by students and examined the usability of the CD-ROM.

- An online survey form that used ranked and descriptive answers as a means of evaluating the effectiveness of the CD-ROM in addressing the learning outcomes of the assignment. A range of themes emerged from the descriptive answers in the online survey and these were used to guide the interview questions.

- Student and lecturer interviews were designed to enquire further into what had been learned by students (achievement of the learning outcomes) and by staff (changes to teaching methods and to the use of the CD-ROM in teaching as a result of student assignments).

Results

The usability of the CD-ROM resource

The data collection conducted through student observation 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 and some similar testing had been carried out that resulted in minor changes to the interface. However, a number of navigational, functional and instructional issues emerged.

Navigation and functionality

It was noted that some students, particularly mature age students and some international students, who had no experience using a CD-ROM previously, had initial problems with the navigation. Once they received a small amount of additional instruction they were able to complete the activity successfully.

Some students who considered themselves to be familiar with interactive software expressed frustration at having to enter sampling details on screen. However, this was intentional because the simulation activity was designed to replicate how a marine scientist would conduct the process in the field. We felt that this component could be automated, but that students might not then appreciate the need to process this detail in the same way they would in the field.

A number of students indicated that the video was too small for definitive identification of one of the target species. This was due to technical constraints in laboratory situations that forced the use of smaller scale video than originally intended. An upgrade of the computers along with advances in video software and playback ability mean that we can rework the CD-ROM to allow full screen video.

Instructional process

There also were 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 or not.

> 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?

Guidance was originally omitted in order to emulate the realities of data collection as closely as possible. However, it was apparent that this instructional consideration was restricting the students' ability to conduct the exercise. Therefore, we decided to guide the student through the activity by providing a trial transect with a comparison table for results before requiring the students to begin their data collection. 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 *et al* 1989).

Achievement of the learning outcomes

Online surveys and interviews with students and teachers were used to evaluate the students' perceptions of the learning benefits of the CD-ROM and the subsequent assignment. Of the 110 students who were asked to complete an online survey form, 60 of the students responded. The resulting data provided some insight into how well the resource addressed the learning outcomes of the assignment:

- 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 the sampling effort 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.

Students also were asked to describe what it was about the CD-ROM that most helped with their understanding, and themes began to emerge that were more clearly elucidated during follow up interviews. Students were categorised according to themes and students from each theme group were interviewed. Teaching staff were also interviewed and asked to comment on how well they felt the resource had assisted students in achieving the learning outcomes for the assignment, the results of the evaluation to date, the themes that emerged and to give their thoughts on ways in which the resource has helped students or failed to reach the goals outlined in the design phase.

The emerging themes

Visual representation. This theme was expressed by students who saw the resource as providing an observer's view of how a sampling regime would be conducted in marine science.

> 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.

'Actual' sampling. 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. 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.

During interviews a number of students alluded to the concrete experience, the importance of being able to carry out the process, instead of being presented with facts.

> It's the hands on stuff 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.

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. 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. Many of the students who were subsequently interviewed also 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 of collecting 'real' data. The student responses reinforced their need to be engaged in the activities of the discipline as a means of authenticating the experience for better understanding.

Difficulties. A number of students referred to the collection of that amount of data and the time involved, 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.

The assignment was more beneficial. A few students indicated that the analysis conducted as part of the assignment was more beneficial to their understanding than their use of the CD-ROM.

> 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, some students commented on how the resource increased their understanding of data collection techniques, and provided the basis for them to describe why they had reached that particular understanding in the subsequent assignment.

> … 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, and someone can tell you that but until you actually see it you don't understand.

Students who had been involved in marine data collection in the past seemed to gain least from the resource.

> I did a conservation expedition and I did it for 3 months counting fish so I'm a bit of an exception, there aren't that many people who are going to have done the research I have done. I guess it gave an idea to people who didn't have any idea how to do fish transects what a fish transect was.

Staff perceptions about the benefits of the CD-ROM

The teaching staff were interviewed and asked to comment on the benefits of the CD-ROM. They described the resource as having assisted the students in their appreciation of the difficulties associated with the sampling of rare species. One lecturer described the usefulness of the resource for students who had never experienced marine sampling. He also commented that one or two students indicated 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.

On completion of the assignment, the lecturers had the following comments to make about what had improved relative to previous years and what had not improved:

> 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 clearly disappointed that the students were not better equipped to interpret their results in light of what they had observed while using the CD-ROM. They referred to the students' inability to explain their results, particularly where patchy distribution and clumping influenced the results.

> Students were told that they were going to use different transect sizes for fish of differing abundances but they seemed reluctant to inquire beyond this.

However, it seems clear from the student responses, that the patchy distribution and clumping of species is a message that they understood as a result of using the CD-ROM. The students said:

- you could see how rare species abundance varied
- it helped with my understanding of clumping of fish species……difficult to obtain by just looking at data

- it was clear that rarer species may not always be observed in small transects if populations are somewhat clumped
- it triggers thoughts about cryptic species under rocks, clumping, what fish you count
- 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.

Discussion

The evaluation evidence indicates that the majority of students felt that the CD-ROM assisted them to achieve the learning outcomes for the assignment. They indicated 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 also were some indirect learning gains resulting from use of the CD-ROM, that can be described as transferable to other research and learning situations. The teaching staff confirmed that students were better able to explain their results in the follow up assignment than they had been in previous years.

However, there were some barriers to progress and a small percentage of mature age students experienced problems with the navigation structure. Changes that will be made to the CD-ROM will ensure that less instruction is required at the outset of using the resource. This along with some simplification of the navigation will assist students whose IT skill levels may obstruct their initial use of this resource. Even so, 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. General moves to provide for the teaching of generic skills, of which use of ICTs is one, will hopefully reduce the level of this problem amongst mature age students.

The evaluation indicated that the CD-ROM did indeed assist the students to gain an insight into the design and conduct of a marine sampling regime. Furthermore, they were better able to choose the best (most cost effective) method for sampling each species. In addition, they gained an experience of a particular sampling technique which they could refer to knowledgably in the subsequent assignment. On marking the assignment, the teaching staff indicated that the CD-ROM did not assist most students in their ability to interpret and explain their quantitative results in terms of their qualitative observations when they were asked to do so in the assignment. However, when questioned during survey and interview, the students were able to point to the patchiness of species distribution and the difficulties in recognising it in their quantitative data. This was the primary factor that also influenced the accuracy and precision of density estimates, and was usually omitted from their written report.

In order to understand this problem, we should consider the core principles of scientific inquiry. These are the ability to formulate hypotheses, collect and evaluate literature and place a value judgment upon it, to gather evidence through data collection, interpret that evidence, and defend conclusions based on the evidence collected and what the literature describes. A gap area is often identified in the gathering of evidence and this CD-ROM simulation assisted in bridging that gap.

Simulations as a tool for learning can authenticate experience for the aspects of discipline content where the practical experience is difficult (Corderoy *et al*.,1993). Simulations are commonly used to integrate process with content, by engaging the learner in the meaningful practices of the discipline (Brown, et al., 1989; Corderoy et al., 1993; Laurillard, 1993; Alexander & Hedberg, 1994). *The Ocean in the Classroom* CD-ROM simulates the process of data collection in the marine environment. It 'leads the student to water'. The question is whether a simulation alone can provide the situation that enables the student to 'think'.

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 simulation clearly provided a valuable means of engaging students in the real practices of the discipline; it also assisted the students to describe the sampling processes used, and to transfer their knowledge beyond the current situation to other research activities. Nevertheless, it is clear that when we also expect the student to interpret and describe in scientific report format, with reference to the literature, they experience problems. This situation could be improved by the students having the opportunity to present their preliminary findings for consideration and discussion by their peers prior to completion of the written component. Indeed, sceptical questioning and imaginative speculation to reflect on experience have been shown to deepen knowledge (Brookfield, 1987). This area could be accommodated in the subject by introducing the use of a reflective journal, or what Edelson (2000) describes as a *progress portfolio,* 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. A short presentation and discussion of findings could reinforce reflective inquiry 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 before they have tested its validity.

Many technology based teaching innovations have been criticised for lack of rigour in the evaluation processes (Alexander and McKenzie, 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. Changes to the CD-ROM, as well as changes to the teaching situation, will be made in an attempt to address some of the areas of concern raised in the evaluation study. However, if we are to truly address the concerns raised by the evaluation there is a need to extend our thinking beyond the resource and the teaching situation towards a change in the way in which we teach scientific inquiry. 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.

Our methods of teaching place the content as the focus of curriculum through lectures in which '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 established techniques, where precision and accuracy are paramount and a testament to the existing knowledge. Students are rarely, if ever, encouraged to analyse the inadequacies of the foundations of that knowledge and so do not discover its limitations, and cannot adequately address solutions or even explore other possibilities as alternatives to that knowledge (Schwab, 1962). Assessment activities complete the cycle, engaging the student in 'measuring' their results through quantitative processes, thus removing them from the realities of what is actually happening. The basic abilities of a scientist to question and critically analyse are at the core of scientific inquiry and yet they are the skills that our current methods of teaching place least value on.

The conceptual principles of inquiry render scientific knowledge unstable and subject to change because research is not guided by the first principle that formed the inquiry, but is further extended by new conceptual principles (Schwab, 1962). Indeed, institutions are frequently under 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 esteemed and quite powerful position. This is particularly true where the 'facts' that are being presented to the students in lectures are those of the lecturers, acquired through the hard toils of their research. In this evaluation project the teaching staff indicated that students were quite prepared to rebut these facts in a tutorial situation. 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 quantitative findings, and what they are seeing, conflicts with what they read.

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, could provide the basis for students to contest the evidence they are presented with. 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 to theory to fact, but see it as a process of investigation and discovery, learning how to hypothesise and critically analyse. This concern with *what is known* rather than *how it has come to be known* is outlined by Laurillard in her analyses of teaching and learning in a tertiary context (Laurillard, 1993). What is needed is 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).

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