

# **UniServe Science**

**Proceedings of  
Improving Learning Outcomes Through  
Flexible Science Teaching**

**Symposium**

**October 3, 2003  
The University of Sydney**

# UniServe Science

**UniServe Science** was established in 1994, under a grant from the then Committee for the Advancement for University Teaching (CAUT), with considerable help from The University of Sydney, to act as a national clearinghouse for the dissemination of information about teaching software in the experimental sciences in Australian universities – specifically in the disciplines of Biochemistry, Biology, Chemistry, Geography, Geology, Physics and Psychology. That grant was for three years. UniServe Science is now fully funded by The University of Sydney and has added Computer Science, Mathematics and Statistics to the client base.

**UniServe Science** aims to enhance the quality of university science teaching in Australia by collecting, maintaining and disseminating information on up-to-date and innovative teaching materials. UniServe Science publishes *CAL-laborate*, an international journal, prepared in collaboration with the United Kingdom Science LTSNs and the Swedish Council for the Renewal of Higher Education. *CAL-laborate* is published in June for the Life Sciences and October for the Physical Sciences and Geosciences and is available online from <http://science.uniserve.edu.au/pubs/callab/>. UniServe Science also conducts an annual national conference which focuses on the enhancement of tertiary science teaching and learning. The conference has two components: the First Year Experience Discussion Forum; and the Tertiary Science Teaching Symposium. The Pearson Education UniServe Science Teaching Award, which is made at the annual Symposium, recognizes teaching that improves student learning outcomes via the innovative and integrated use of information technology. Notes from the FYE forums are available online from <http://science.uniserve.edu.au/disc/fye.html>.

Papers for the 2003 Symposium, ‘Improving Learning Outcomes Through Flexible Science Teaching’ have been reviewed to meet the Department of Science and Training standard for research conference publications.

The full papers were peer reviewed by at least two members of a national review panel that was chaired by Associate Professor Ian Johnston, Director, UniServe Science. For those papers deemed to be worthy of refereed publication, authors were provided with feedback from the reviewers and asked to make appropriate changes.

The Symposium was attended by academics from across Australia and the proceedings is distributed nationally and internationally in print and from the Web (<http://science.uniserve.edu.au/pubs/procs/>).

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Published by: UniServe Science, Carlaw Building (F07), The University of Sydney, NSW 2006  
<http://science.uniserve.edu.au/>

Editor: Kaye Placing  
ISBN: 1 86487 490 2  
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Pearson Education Australia was a proud sponsor of this UniServe Science symposium. Pearson Education supports UniServe Science's aim to promote the use of technology in science teaching and learning.

# Rethinking the teaching of science: insights from research into student learning

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**Abstract:** The declining interest in science at primary, secondary and tertiary levels has been well documented over recent years. While the reasons for this are complex, we need to reconsider the way science is typically taught if we are to provide those students who have chosen to study science with a rich and rewarding experience. In particular, it is proposed that we need to teach science more like the way science is practised, that is, as an exciting field of intellectual inquiry rather than a process of memorising and recalling large quantities of information. This will mean radically rethinking what it means to learn science, how science should be taught and how learning should be assessed. There is now a rich literature concerning both how people learn and ways to facilitate learning through effective teaching strategies. However, much of this knowledge is unknown to those teaching science in universities. This presentation reviews some of the latest insights to emerge from research into student learning and considers the implications of this research for science teaching.



# Developing a learning environment that encourages deep learning outcomes

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*There are those who see a thing and ask why, while others dream of things that never were and ask why not?*  
J.F. Kennedy, 1963

*Abstract: In this paper we report on the development of an authentic learning environment, the tropical island of Lys, that we used to facilitate high quality student learning in a third year subject designed for environmental and ecological scientists (NRB572 'Terrestrial Ecosystems'). Lys provided the conceptual framework around which students engaged with web-based learning resources, lectures, practicals, paper-based resources (such as study guides and handouts), as well as a virtual tour of the island, and most importantly an integrated set of assessment tasks that obliged students to develop a critical understanding of fundamental ecosystem processes. Our students expressed conspicuous levels of satisfaction, enjoyment, interest and engagement from their learning experience together with significantly enhanced learning outcomes, which were both self- and formally identified. In this paper, we report on how we used several 'principles' of curriculum design so that others, irrespective of discipline, could use similar approaches to achieve similar learning outcomes with their students.*

## Aims

We sought to:

- develop a challenging, interesting and engaging learning environment;
- produce assessment tasks that oblige students to think creatively and critically; and
- design assessment, that is realistic, inter-linked and cumulative in effect.

## Introduction

Dearn and the research literature shows that for students to constructively engage with learning tasks and adopt a deep learning approach, we need to employ a range of teaching interventions integrated into a coherent teaching and learning *strategy*. For example; to develop a challenging and interesting learning environment, Kember (1998) recommends the use of vivid examples and contextual learning to facilitate student engagement with the material. This approach helps students to build their learning on a scaffold of academic/real world/life experience. In parallel, Biggs (1999) argues that students spend more time on the task of learning when they experience constructive alignment between learning objectives and outcomes. Such approaches facilitate high quality engagement with learning tasks, in part because students find the material of greater interest and easier to understand, but also because they associate their work with a sense of involvement, challenge, fulfillment, achievement, and satisfaction (Connell 1967; Svenson 1977; Brookfield 1985, 1995).

Because of our awareness of this literature, we developed a teaching and learning strategy providing students with a learning environment that would oblige them to adopt deep, constructive approaches to their learning. We discuss the principles we used to achieve these outcomes below.

### **Curriculum design principle 1: develop an interesting and engaging learning environment**

In our teaching we challenge our students to understand the interactions between plant and animal assemblages so that they develop their abilities to predict and control such interactions in the field (a skill for which there are any number of potential applications in today's environmentally conscious world). The teaching challenge is that plant and animal assemblages that readily illustrate such interactions are difficult to find. Inevitably, real case studies are:

- limited in their scope (obliging educators to use multiple case studies that can potentially confuse learners); and
- often clouded by peripheral detail (which distracts learners from the objectives we use these examples to illustrate).

The central part of the solution to this problem was the development of a case study using the tropical island Lys (pronounced Lease), located 626 km off the coast of Queensland, Australia. The island possesses a range of plant, animal and geological features that do not co-occur elsewhere. Around this unifying theme, we developed student learning resources and supporting information detailing the physical and ecological processes on Lys from publications and other resources we collected on a recent scientific expedition to the island (e.g. see Figure 1; and our publications about the island that you can access from the unit web site<sup>1</sup>). Due to the large topographic relief over short distances, the island illustrates the potential interactions between plant and animal assemblages that do not ordinarily occur adjacent to each other. The distribution and abundance of these plants, animals and landforms provide an ideal natural laboratory in which to examine dynamic ecosystem processes not possible anywhere else in Australia or the South Pacific region. Added to these resources, the teaching and learning strategy developed for NRB572 integrates the use of lectures, other web-based resources, practical exercises, a field trip, and an *integrated* set of assessment tasks. The *combined* effect of this teaching and learning strategy is to support and oblige students to adopt a deep approach to their learning.

Figure 2 illustrates the range of resources used, their sequence and organisation. The figure also shows how we integrated the resources – you will gain greatest benefit through viewing the figure in conjunction with the explanatory text on the following page. To illustrate ecosystem processes to students, we organized NRB572 to comprise three modules. We designed these modules (described in Figure 2) to become cumulative in their effect. To support student learning, each week we deliver two hours of lectures plus an average of two hours of practical work (distributed between laboratory/tutorial and field work). We also provide:

- paper based and online learning resources (e.g. handouts, practical tasks and briefing material); and
- online content (e.g., a virtual rendering of the island – demonstrating relevant readings, resources, links to web sites, etc – e.g. see Figure 1).

We designed the NRB572 curriculum to ensure that the students' developing knowledge resulted from them having to complete tasks that ensured they *engaged* with the learning materials and resources they identified. We used *two practical exercises* (with an entirely formative function), together with *two assignments* (the second comprising parts A and B). For each assessment item, we framed the questions in a divergent fashion, allowing each student the opportunity to pursue and develop their own knowledge and understanding within the context of the unit's aims and goals. We also designed each practical and assignment to form the basis for, and provide the requisite knowledge for, completing the next assignment. The progression from assignment one to two relied on: developing a critical knowledge framework (assignment 1); developing a focus on understanding the theoretical principles (assignment 2, part A); and developing an application focus requiring students to test their understanding (assignment 2, part B).

We augmented this progression through *a field trip*, timed to occur after students had completed module 1 and had submitted their first assignment. The field trip served to consolidate the students' ideas and knowledge gained from module 1 and to introduce them to key concepts we would consider in modules two and three.

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<sup>1</sup> For your convenience you can access the following publications: Cooke et al. 2002; Meyers et al. 2002, and Rigby et al. 2002 from: <http://flex.sci.qut.edu.au/units/nrb572/nrb572-lys.htm>

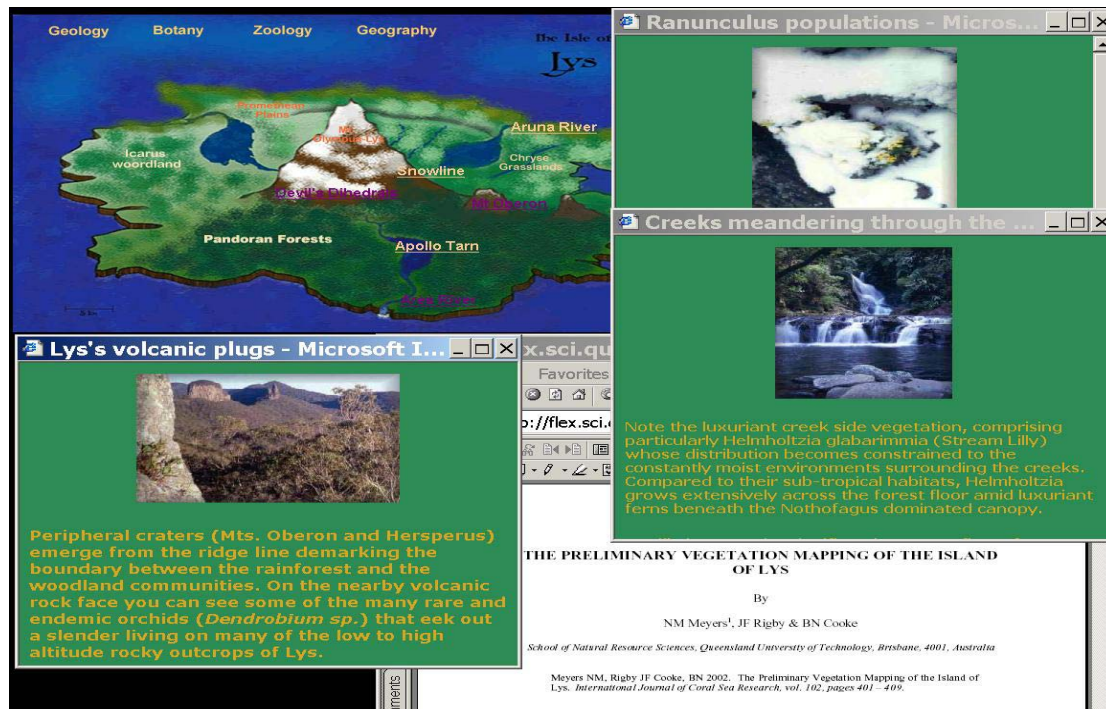


Figure 1. Examples of learning resources developed to assist the students to undertake a virtual fieldtrip around the island of Lys. Throughout their journey students can obtain specific details on any of the three adjacent ecosystems, namely: grasslands; woodlands; and rainforests

Considered together, the resources we described allow us to ask many ‘what if...?’ type questions designed to guide the constructive development of critical thinking processes (Brookfield 1985; Bodner 1986; Halpern 1998, 1999). Specifically, through the assessment tasks set, we are able to *oblige* the students to synthesise a broad range of information, identify useful resources, formulate and test hypotheses and, ultimately, to apply their developing understanding to novel problems. Thus, the cognitive tasks required to successfully complete the assessment items derive from an engagement between the students and the learning materials which is driven by those assessment tasks (Boud 1982; Ramsden 1992; Biggs 1999; Nulty, Vegh and Young 2002).

### Curriculum design principle 2: set assessment tasks which oblige students to think critically

Having provided a description of the resources, we now illustrate how students progress and interact with each of the curriculum elements and assessment tasks described above. We understand that students are strategic, purposeful adults – who recognise that to get a good grade requires them to complete assignments as well as possible (Ramsden 1992, 1993; Tang 1994). In providing students with the assignment tasks in the first lecture, we ensure that students focus their study on accumulating appropriate resources and knowledge. Moreover, students begin thinking about how each fact/idea relates to their ability to complete the assignments. This creates an environment in which students try to relate the teaching and learning to the assignment tasks. Let’s examine the requirements of assignment 1 to illustrate this principle:

- using palynological records, explain changes in the flora and fauna of Lys over time; and
- explain how the flora and fauna of Lys came to achieve their current distributions.

Adopting a strategic approach to the unit, students will ask themselves how they will achieve their desired grade in the unit. This point deserves further clarification, because we use the students’ adaptive response to assessment to direct their learning behaviors. When we provide an assignment (in the form of an assessment item), we provide a framework around which students can construct increasingly complex knowledge which in turn will help them to formulate their answers to the assignment. It follows that students must complete particular learning tasks, by engaging with the learning resources we provide, before they can answer the assignment. Thus, by our careful choice of

assignment, we are setting the students up to engage in particular learning behaviours: students begin the unit by examining the unit outline; consider the specific details of the teaching and learning strategies of the unit made explicit in lectures; and look at the assessment items they have to complete. Then they recognise that various learning resources we provide (elements of module 1 and practicals 1 and 2) provide the foundations necessary for them to complete their assignments. Almost inexorably, they are led to use the materials provided to help them to complete their assignments.

Resources	Lectures	Week	Practicals	Framework	Assignments
Unit Outline					
Handouts	Module 1 Palaeo-diversity	1	Practical 1	The Island of Lys	Assignment 1
		2			
Handouts		3	Practical 2		
		4			
Handouts		5			
		6			
		7	Field Trip		
Study Guide	Module 2 Eco-principles	8			
		9			
		10			
Study Guide	Module 3 Restoration Ecology	11			
		12			
		13			
					Assignment 2 Part A
					Assignment 2 Part B

Figure 2. A description and timetable for the delivery of curriculum items, that (taken together) are designed to elicit deep learning outcomes in students studying NRB572 – *Terrestrial Ecosystems*

### Curriculum design principle 3: set realistic assessment tasks which are interlinked and cumulative in effect

The first assignment requires students to discuss the dynamics of Lys' plant and animal communities and ecosystems over time. To complete assignment 1, students have to read, understand and apply the information contained in handouts, practicals and online resources. To illustrate the learning outcomes for students engaging in this process, we can examine NRB572's practicals 1 and 2.

First, students recognise the importance of completing the tasks set in practicals 1 and 2 because they can see that this will help them to develop the knowledge they require to complete assignment 1. The first practical involves students examining the historical pollen record of Lys to determine the island's plant species composition over a span of 20,000 years. In order to analyse this information, students must undertake a number of cognitive tasks – each of which produces a desired learning outcome. By completing this analysis, students learn some ecological principles (a learning objective of this unit) which we expand on in Module 2. In addition however, students discover that the pollen records do not match the current distribution of the plant communities on the island. Students begin to question the validity and assumptions associated with the collection and interpretation of such data. They realise that data of this kind are necessary, but not sufficient, to provide explanations of the current and past distribution of the island's flora and fauna. Students recognise that they require additional information. Soon after this they realise that the additional data might be found in the materials we provide for the second practical.

Practical 2 requires students to investigate the animal fossil records from two localities on the island. This investigation obliges students to undertake the cognitive tasks described in Figure 2 (with consequent outcomes described in our curriculum design principles). By conducting the investigation of fossil records, students derive some (further) ecological principles (which we expand on in Module 2). Students realise that the animal fossil data can tell them that certain animals occurred during times when certain plants were abundant. However, they also recognise that without specific ages for the animal fossils they cannot determine when the overlap between plants and animals occurred. In combination, the outcomes of practicals 1 and 2, together with tutorials demonstrate to students that the fossil data *augments* the pollen data – thus allowing students to



derive more sophisticated models of Lys' past. Students recognise the importance of this information because it forms the basis of the knowledge/information they need to complete assignment 1. Assignment 2 builds on and similarly requires the understanding that students develop in assignment 1.

## Outcomes and evaluation

We gathered two forms of evaluative feedback on the development of this unit throughout its implementation: feedback from students (either in response to formal questionnaires or unsolicited comments); and, feedback in the form of the students performances on assignments, practicals and in field work. While students work exhibited a very high standard, their feedback helps to illustrate the effectiveness of our curriculum design.

### Student feedback: challenging and interesting learning environment

- The Lys example is fantastic. It really encourages me to think about what we are learning in class and apply it to an unfamiliar situation (i.e. Lys).
- The whole Lys concept really provided the opportunity for exploration and novel thought.

### Student feedback: assessment that obliges students to think critically

- [The assessment] encourages student participation, concentration and motivation to learn.
- [The assessment] actually makes us think.

### Student feedback: assessment that is realistic, inter-linked and cumulative in effect

- The assignments were real brain-ticklers, encouraging us to bring together knowledge from a whole bunch of areas.
- [The subject] ... is well structured, and the progression of lectures/tutes/pracs/field work and assessment items, follow a clear path to the end of the unit objectives.

Results from Student Evaluations of the Unit (SEU) bear out this statement with a score of 4.7 out of a possible 5 (corresponding to a rating of this unit in the top 2% of all units offered in the QUT Faculty of Science). This SEU score, combined with the student feedback quoted throughout the document demonstrates high levels of student satisfaction with the quality of their learning.

## Conclusion

We need to explain, that the island of Lys does not exist. We designed the island as a completely fictitious, yet authentic organising theme for students' learning. Each of the learning resources explained aspects of Lys, but did not provide interpretations or conclusions that may inhibit the development of students' interpretative skills that the assessment tasks required. We designed the island to provide a guided and supported learning environment to ensure students learnt about science through engaging with the scientific method.

Lys represents an example of how online resources, together with a carefully designed curriculum can and do produce high-quality student engagement and learning outcomes. Using the principles of curriculum design outlined, we suggest that educators, in any discipline, can construct similar learning environments, online resources and assessment strategies that require students to adopt deep approaches to their learning

In our final lecture, we told the surprised students that Lys did not exist. Despite this, students said that Lys 'motivated [them] to learn' and 'changed the way [they] learned' because of the 'attention to detail' and 'linked assessment tasks.' Student's seemed to enjoy most, the chance to apply their learning to a 'real world problem.' Like the students, we have learnt much from the unit. To paraphrase and contextualise Kennedy's script writer, quoted at the start of this paper: as educators, we have the tools to help our students to learn, the only limit is our imagination!

## Acknowledgements

This paper represents a substantially modified version of: Meyers, N. M. and Nulty, D. D. (2002) *Implementing an assessment strategy which facilitates student engagement with learning materials* presented to the Joint Northumbria / EARLI Assessment Conference, 28th–30th August 2002, Northumbria University, UK. The full paper is available online through the British Education Index: <http://www.leeds.ac.uk/educol/documents/00002240.htm>.

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