An evaluation of first year chemistry students: class performance versus use of Internet-based supplementary materials

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Introduction

Over the last ten years the Internet has acquired an aura as a vital resource for learning. It acts as a distributed learning environment available all day every day, a powerful tool for students with too many demands on their time. A web search of virtually any academic topic will turn up a plethora of sites from universities all over the world containing a range of information, from simple lecture notes, sample examinations, interactive problems or examinations, animations, interactive lessons or practicals, etc. The amount of time and effort devoted to production of these materials is incalculable. There has been virtually no research, however, on whether such resources improve student learning or performance in classes. A basic search of *Current Contents* came up with few literature citations; many of these papers report student or faculty opinion of the value of the resources (Agius and Bagnall, 1998; Chang, 2001; Morss, 1999; White and Hammer, 2000). Of the papers that examine student learning/performance compared to use of Internet resources, many fall in the medical community (Agius and Bagnall, 1998; Bell et al., 2000; Erstad and Tong, 1999; Harrold and Dessele, 2000; Hedaya, 1998); the remainder cover classroom learning environments (Buchanan, 2000; Epstein et al., 2001; Frederiksen and Donin, 1999; Poirier and O'Neil, 2000; Sosabowski, Herson and Lloyd, 1998; Thelwall, 2001).

Over the last seven years the author has developed a suite of web-based supplemental materials for first year chemistry students. The intention of the web site materials is to provide a myriad of resources so students with different learning styles will have the best opportunity to perform well in class, as well as provide resources available to students with varied work, class, and family schedules. These materials cover class topics for introductory, general, engineering, nursing, and chemistry major classes, and include well over 250 files including:

- administrative materials (announcements, syllabus, lecture/laboratory schedule);
- narrative format edited lecture notes (Lecture Packets);
- old examinations, as practice test and with detailed explanations of answers;
- interactive practice problems, with hints for wrong answers;
- course specific discussion areas;
- take home quizzes as *Acrobat* files, and answer keys;
- detailed explanations to current examinations;
- grade access; and
- course discussion area.

The edited lecture notes are intended to serve two purposes: save class time by removing the need for students to take many notes and copy problems; and improve student learning by providing an environment where students listen, analyze, and **integrate** ideas instead of taking dictation.

Was it worth the time spent creating these files? How did students use these materials? Did it make any difference in their level of learning or performance in the subject? If nothing else, did they find the materials useful? We are all confident that our web resources are useful to our students, but if we know more about what materials are used, and how, we can focus energies on those materials that make the most difference to students – especially the poorest performing students.

Procedure

Data was collected at Arizona State University (ASU) from 1997. The General Chemistry class is the two semester science and pre-med sequence (called 1A and 1B below); chemistry majors are not in this class (they have their own class). Introductory and Engineering Chemistry are each one semester classes: Introductory has agriculture, nursing, business, and liberal arts students.

The analysis of student use of class web-based materials has evolved over the years as better data mining techniques were discovered. The first attempt at collecting this information involved using page counters to determine what types of materials were most used by students.

The classes are typically 120-175 students. The following data was collected over two years:

Page material	General Chemistry 1A	General Chemistry 1B	Introductory Chemistry	Chemistry for Engineers
Edited lecture notes	>100%	>100%	>100%	>100%
Interactive problems	(15%)	28%	29%	N/A
Old examinations	>100%	74%	N/A	N/A
Explained current examinations	84%	78%	(47%)	>100%

Table 1. Average student hits as percent of class enrolment (from page counters)

Note that less than one third of the class (based upon page counters) used interactive problems; one quarter of the class did not look at old examinations. Even explanations of their own examinations were only accessed by about three quarters of the class – except for the Engineering students.

The page counters give some indication about how students use the course materials – but who are the students that access the old examinations? Who are the students that don't access explanations of their own examinations? The students performing well in class? Those performing poorly?

Students that perform poorly in class – are they taking advantage of these web-based resources? Are the high performing students using these resources? Perhaps students do poorly in class because they don't use these supplementary materials, and high performing students do. The student usage data as determined by page counters raises more questions than it answers. The problem with web-page counters is that we don't know what each student is doing, just the class as a whole.

Results

By March 2000 the class suite consisted of nearly 200 web pages, all cross-referenced and interlinked. Some research was done into generating a database of hit counters linked to student logon ID, but there was little time to learn how to do the programming. Fortunately, in May ASU started using *Blackboard* as a resource for faculty to create web sites for their classes. *Blackboard* (http://www.blackboard.com/) serves as an umbrella program within which the faculty create web pages using a simple editor, create headers and navigation, post files, and use an in-built discussion area (among many other utilities). The discussion area was a desired application, but the ability to track student usage of the web site was the most attractive aspect of *Blackboard*. As each student needed to login to the *Blackboard* program, the data could now be collected on which students accessed which pages.

The summary data for nine classes over three semesters and two summer terms are found below. The data have been analyzed to evaluate:

- which portion of the students use which materials;
- whether students change how they use the web resources; and
- whether there is a correlation between student use and grade.

The July session 2000 of Chemistry 1B was the first class in which usage of the web site was tracked for each student:

Class ranking	Old examinations and explanations	Current examinations explanations	Practice problems
Top 25%	4.1	1.9	4.8
Second 25%	9.1	1.7	6.7
Third 25%	10.2	2.7	8.2
Bottom 25%	7.2	1.6	4.9

Table 2. Student usage (average hits/student) and final grade data from ID tracking
Chemistry 1B Summer 2000

So who are the students accessing these materials?

- Students in the top 25% of the class access the materials least – perhaps they need little supplemental help.
- Students in the third 25% of class access the materials the most – they must find these materials helpful. Are these former D students who are using these resources to boost their grades?

The full data for two different classes over the three 2001 terms (Spring, Summer, Fall) are appended to the paper. The most illustrative data appears within the text.

First semester General Chemistry (1A)

Differences were observed in the use of the web-based materials for the Spring and Fall Chemistry 1A classes. The Spring class is an off sequence group, with students that failed the preceding semester, and other students who for one reason or another have gotten off track; these students are typically the poorest performing class taught all year. The Spring group accessed lecture notes and explained examinations 1.3-1.6 times – indicating they printed out the materials to use them. The old examinations were accessed much more by the middle and poorer students; these resources appear to be more valuable for studying. The Fall group accessed the lecture notes about the same amount no matter their class ranking, but the bottom 20% of students clearly used the old examinations and explained current examinations less than other fractions of the class – one half to one third that of the top 20% of the class.

Class ranking	Lecture notes hits/student	Old examinations and explanations hits/student	Current examinations explanations hits/student
Top 20%	26.0	7.6	6.1
Second 20%	20.6	7.8	5.0
Third 20%	20.1	5.4	5.7
Fourth 20%	15.5	4.9	3.3
Bottom 20%	20.2	3.0	1.9

Table 3. Chemistry 1A Fall 2001
n = 152(158); grade distribution: A=18% B=24% C=30% D=17% F=5%

Students taking the class in the summer term, in which the material from a normal 14 week semester is covered in five weeks, accessed materials much less than students in the Fall and Spring semesters. Essentially all students had 1.0-1.5 page hits per student for all supplement types. This suggests that the summer students simply print the materials out and use them – the time compression of the class precludes time to repeatedly access the resources.

Second semester General Chemistry (1B)

Summer session students for this class are usually pre-med students – highly motivated, hard working students who will take advantage of any opportunity to excel in class. The summer session class showed essentially no variation in student usage of the web resources – all groups by class rank accessed all materials the same amount: 1-1.5 hits per student. These students, like the 1A summer students, simply print the materials out and use them in the time-compressed environment of the summer class. These summer classes are regularly the best students all semester, with over 80% of the class earning A or B.

Class ranking	Lecture notes hits/student	Old examinations and explanations hits/student	Current examinations explanations hits/student	Practice problems hits/student
Top 20%	13.6	4.8	9.2	10.2
Second 20%	14.7	4.2	10.3	10.8
Third 20%	14.4	3.9	10.9	9.2
Fourth 20%	13.0	3.6	8.9	8.2
Bottom 20%	8.2	2.7	3.3	3.5

Table 4. Chemistry 1B Fall 2001
n = 236(243); grade distribution: A=31% B=40% C=16% D=10% F=1%

The Fall semester class had much higher hit rates than the summer, as was observed for the first semester class. Note that for each type of material, the bottom 20% of students had the lowest hit rates – half to a third that of the highest rates for all but the lecture notes.

Additional analysis was done of student hits by performance on examinations versus hit rates. The goal in this effort was to try to identify how students altered their preparation for examinations (as measured by their use of the web resources) as the term progressed. The data below is representative of that observed for all classes:

exam4	top 20%	second 20%	third 20%	fourth 20%	bottom 20%
exam1 chapter notes	12.3	13.0	13.9	14.2	11.3
exam2 chapter notes	12.9	13.9	14.9	15.2	12.0
exam3 chapter notes	12.9	14.1	14.7	14.9	12.0
exam4 chapter notes	12.9	13.8	14.7	14.9	12.0
old exam1&key	5.7	3.7	4.0	3.6	3.1
old exam2&key	5.7	4.1	4.7	4.6	3.6
old exam3&key	4.0	4.3	4.2	3.7	2.7
old exam4&key	3.1	3.9	3.2	3.0	2.5
Current explanations exam1	12.3	12.1	11.1	13.2	13.3
Current explanations exam2	10.1	10.5	9.0	10.7	11.7
Current explanations exam3	9.3	8.7	7.6	9.5	10.7
Current explanations exam4	6.3	5.8	5.4	7.9	7.4
exam1 sample problems	10.1	8.2	9.6	8.0	7.7
exam2 sample problems	10.1	8.3	9.4	8.0	7.7
exam3 sample problems	9.8	8.4	9.5	8.1	7.8
exam4 sample problems			none produced		

Table 5. Chemistry 1B Fall 2001
Student hit rates for Examination 4 materials- lecture notes, old examinations, current explained examinations, and sample problems

The data above show that students do not change how they use these supplementary materials. It is surprising – it doesn't matter if a student does well or poorly on the first examination, they do not change their use of old examinations, explanations of their examinations, or even use the sample problems more.

This might be due to limited usefulness of the web site materials. Student surveys were conducted during the final examination over several semesters and different subjects to determine student opinions and satisfaction with the course materials; students were asked to rate (1-5, 1 being most helpful) how helpful they found:

- lecture notes;
- old examinations;
- explanations to their own examinations;
- sample problems;
- would more sample problems be more helpful? and
- textbook problems.

All classes had the same responses (within a rating of 0.2), the results for the pre-med 1B class Fall 2000 are representative of the survey results:

Lecture notes	Old examinations	Explanations of their examinations	Sample problems	More sample problems?	Text problems
1.3	1.7	1.2	1.5	1.4	2.7

Table 6. Student opinions of helpfulness of supplemental materials (1-5, 1= most helpful)

So it appears that lack of change in student use of the web site is not based upon poor usefulness to the students.

Conclusions

- The lowest performing students seem to rely on old examinations for preparation more that the other groups. They appear to be less concerned about checking their wrong answers on tests (based upon accessing explanations to current tests). These students often don't take as much advantage of the practice problems as the middle half of the class; are they discouraged by their performance? – or do they perform poorly because they don't utilize the supplementary materials as much as their classmates?
- Student use of resources does not change throughout the term – even despite poor performance on early examinations.
- Student use of the web resources is not necessarily predictive of subject performance; however, the general trends observed in the first bullet above indicate there may be a fundamental difference between the weaker students as a group and their use of technology.

Clearly new questions arise as more data is collected. The next step in this project would involve interviews of selected students to get more information about why they accessed resources the way they did. For example: why did one student access the lecture notes for the first half of the class over 70 times per chapter? And why did the same student then drop down to an access rate within the class average?

The real goal of this study is to try and correlate student learning to use of supplemental Internet based resources. In this paper, the student's grade on examinations and final grade in the class have been used as a measure of their learning – their mastery of the subject; this is of course problematic, as a student's performance in class need not have much to do with the learning that occurred. Pre- and post-interviews are necessary to get a measure of actual student learning.

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The data for two different classes over the three 2001 terms (Spring, Summer, Fall) are below:

Class ranking	Lecture notes hits/student	Old examinations hits/student	Current examination explanations hits/student
Top 20%	1.5	1.0	1.4
Second 20%	1.6	11.0	1.5
Third 20%	1.5	3.6	1.3
Fourth 20%	1.5	1.0	2.1
Bottom 20%	1.5	3.4	1.6

Table 7. Chemistry 1A Spring 2001
n = 300(329); grade distribution: A=14% B=29% C=30% D=20% F=8%

Class ranking	Lecture notes hits/student	Old examinations hits/student	Current examination explanations hits/student
Top 20%	1.5	1.0	1.4
Second 20%	1.5	1.0	1.5
Third 20%	1.4	1.1	1.5
Fourth 20%	1.5	1.1	2.0
Bottom 20%	1.5	1.0	1.6

Table 8. Chemistry 1A Summer 2001
n = 56(59); grade distribution: A=28% B=28% C=32% D=12% F=2%

Class ranking	Lecture notes hits/student	Old examinations and explanations hits/student	Current examinations explanations hits/student	Practice problems hits/student
Top 20%	1.5	1.0	1.4	0.6
Second 20%	1.5	1.0	1.5	1.0
Third 20%	1.4	1.1	1.5	0.8
Fourth 20%	1.5	1.1	2.0	0.9
Bottom 20%	1.5	1.0	1.6	0.6

Table 9. Chemistry 1B Summer 2001
n = 66; grade distribution: A=51% B=45% C=5% D=0% F=2%

ChemCAL Prelabs Online

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Introduction

The teaching of science in the Australian university system is challenging. Complex key concepts must be developed in the context of increasing class sizes and a diversity of interest and ability in the student body. Student expectations about university study are changing, with signs of what McInnis (2001) terms 'disengagement' from university study. There is an expectation that university will fit in with students' lives, rather than the other way around. With a significant increase in the proportion of students working and in the number of hours of part-time work they undertake (McInnis, James and Hartley, 2001), students are increasingly seeking access to forms of learning they can use off-campus and at times convenient to them. James (2000) has found that students simply expect technologies to be part of their study and learning experience at university.

The University of Melbourne has included a computer aided learning component in its first year chemistry courses for around 10 years (McTigue et al., 1995). Our current suite of web-deliverable interactive multimedia tutorials, *ChemCAL Online* (Coller and Tregloan, 2001), was developed during 1999-2001 and covers a full range of topics typical in a first year chemistry syllabus. Chemistry 610141 and 610142 are each one semester subjects, with enrolments of around 1000; 610141 is a prerequisite subject for 610142. Each subject includes 12 topic modules, representing a total of around 10% of the workload of the course. Each module is designed to take a student 30-40 minutes of study time. Students are encouraged to make their own decisions about how to use the modules in their study program, but are advised to pace themselves at about one module per week.

The interactive animations in *ChemCAL Online* have been developed to provide students with engaging ways to review and explore central ideas in chemistry and to help them to make connections between those ideas. Where possible, a concept is presented in a way that must be explored actively. Integration of the resources into the course is important and our lecturers link specific pages in *ChemCAL Online* to their *PowerPoint* presentations in lectures, to encourage students to try the interactivity out for themselves in their own time. The module structure is flexible enough that we can easily reorganise the content from year to year or to complement a specific course.

In 2001, the *ChemCAL Online* program was developed further, with the addition of the Online Prelab resources – 8 modules of questions and animations to be designed for each of 610141 and 610142, which students must complete before undertaking each laboratory class. The objective was not to replace direct laboratory time or experience for students, but to increase the effectiveness of this aspect of our undergraduate teaching program. This paper outlines the development and current versions of *ChemCAL Online* and *Prelabs Online* in use at The University of Melbourne. Student patterns of use of the resources are summarized and students' experience of the products examined.

Prelabs Online

Laboratory based teaching is at the heart of an experimental subject like chemistry and the aim of the *Prelabs Online* project was to use our experience in multimedia development to enhance the effectiveness of our major first year laboratory courses. The conventional preparation for laboratory work is a brief written 'prelab' exercise, handed in to a group demonstrator before a class.

Beginning with a pilot project in 2001 and a full set of prelab modules on-stream for the Semester 2, 2001 course, *Prelabs Online*, set out to:

- replace each written prelab with a multimedia module to be undertaken shortly before the class. The intention was to require participation and individual responsibility for these tasks in a way that the written prelabs need not do.
- use the techniques available to us through our ChemCAL Online system to present and review the context of a particular experiment together with various aspects of the laboratory procedure, using animations, videos and interactive questions. Some examples are given in Figures 1 and 2.
- provide demonstrators with access to the prelab files before a class, so that they could confirm successful completion of the module – a requirement for a student to begin the class.
- use the multimedia modules to link the laboratory aspects of the course more specifically to the lectures and other aspects of the course – addressing a commonly expressed difficulty for students – while also emphasizing the aspects of the laboratory experience which focus on manipulative or measurement skills and experience in the handling of materials.

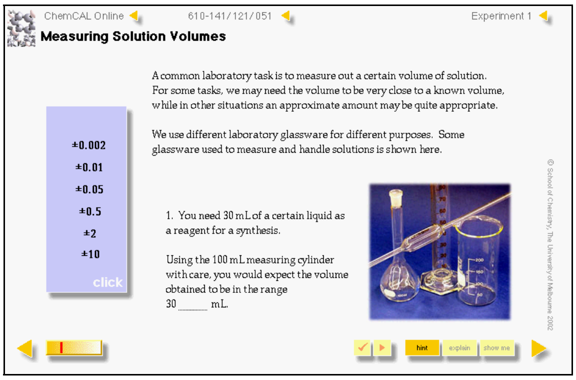

Figure 1. Measuring Solution Volumes

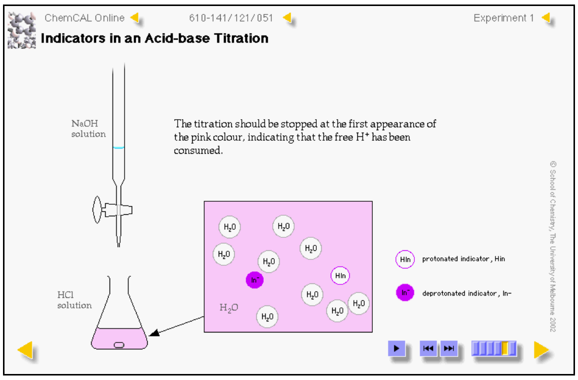

Figure 2. Acid-base Indicators

Our objective is to make time spent in laboratory classes more effective – not to replace, but to significantly improve and enrich the practical laboratory experience for our students. The intended learning outcomes are an improved understanding of experimental chemistry and an increased level of laboratory skill in our graduates. The pre-laboratory modules in this project must not be a major additional study burden and were designed for 15-30 minutes of student time before each experiment. The nett change in the required student workload was expected to be minimal. Once implemented, the impact on staff workload was also expected to be minimal. Laboratory demonstrators have been relieved of hand-marking a total of over 20,000 written prelabs a year. Many routine and repetitive questions to demonstrators and tutors are now handled through the online resources both prior to and during laboratory classes. Demonstrators can use their skills and knowledge to work with individual students on more sophisticated and detailed problems associated with laboratory work.

Patterns of use

ChemCAL Online and the *Prelabs Online* resources now form an integral part of our first year courses and the system delivers over 600,000 pages of information, interactive questions and animations to students in our first year classes each year. Server log information and data returned by the *ChemCAL Online Shockwave* objects, provides us with pattern of use and performance data.

For Chemistry 610142 in Semester 2, 2001, we found that the use of Prelabs was largely constant across the semester as expected for a compulsory component of the practical program (Figure 3). The peaks in use correspond to the commencement of practical work (in Week 2 of the semester) and to new modules coming online for the first time. Weeks 38 and 39 relate to a mid-semester break.

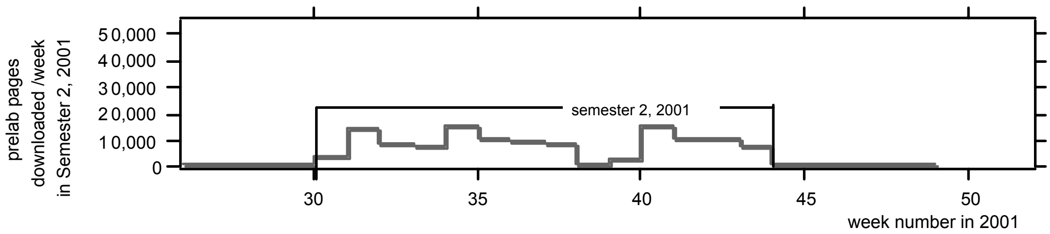

Figure 3. Prelab pages/week during Semester 2, 2001

The *ChemCAL Online Prelabs* were designed to take about 20-25 minutes to complete. This objective has been realised as illustrated by the example below showing a distribution of student session times for Experiment 5 (Figure 4), though it is also important to note the wide range of times individual students choose to spend on the tasks required. The typically high average mark for the prelabs (Figure 5) suggests that students have a good understanding of the concepts presented. This conclusion was also borne out in the results of the focus group interviews.

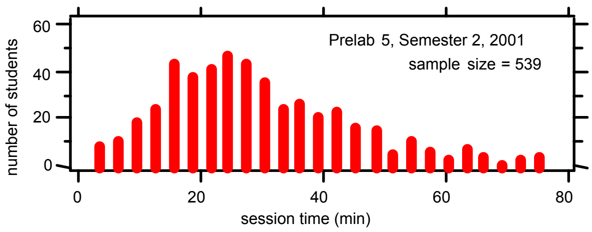

Figure 4. Sample distribution of session times for a prelab module

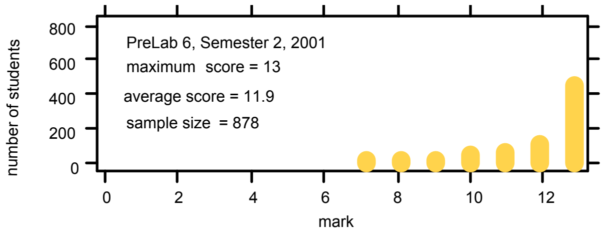

Figure 5. Sample distribution of marks for a particular module

For all first year General Chemistry subjects, the 'non compulsory' *ChemCAL Online* modules are used consistently across the semester with dramatically increasing use towards the end of semester (Figures 6 and 7). This pattern is consistent with students using the modules to assist their learning across the semester, with intense use to aid their revision and examination preparation. The sharp decline at the end of week 45 marked the conclusion of the examination in Chemistry 610142, the largest of the Semester 2 chemistry subjects. By comparison, once practical work was completed few students felt the need to access the Online Prelab modules (Figure 3).

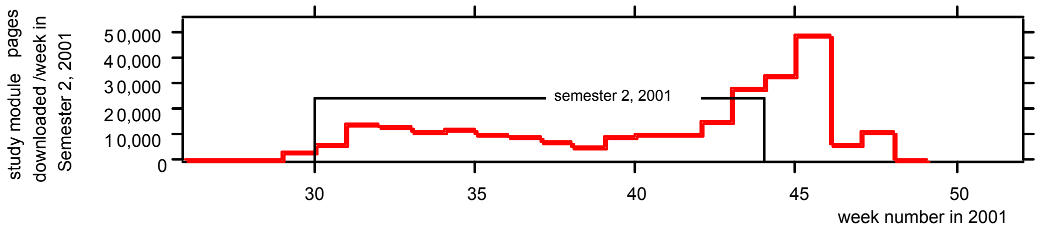

Figure 6. Study module pages/week during Semester 2, 2001

The total of Online session times for students varied widely, although the 'average' student appears to spend between 5-10 hours per semester using *ChemCAL Online* (Figure 8).

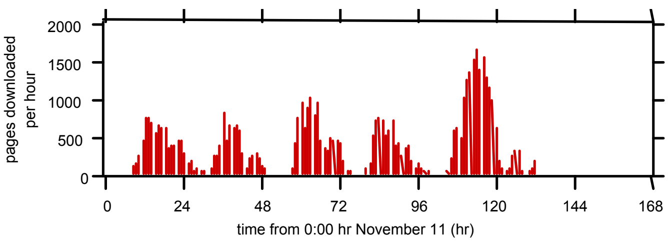

Figure 7. Hourly deliveries in week 45, 2001

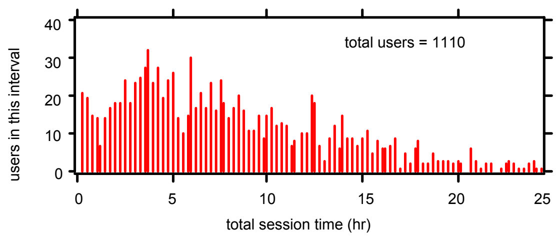

Figure 8. Total Semester 2, 2001, session times

Students' experience

Our evaluation during 2001 of *ChemCAL Online* and *Prelabs Online* incorporates observations of patterns of use, pre-use and post-use questionnaires and focus group interviews with students. Questionnaire and interview data relevant to *ChemCAL Online* and interview data about the Prelabs are reported here. Interview data indicated that students found *ChemCAL Online* useful for their learning and in reinforcing chemistry concepts learned through other mediums. In the post-use questionnaire, there were four items that related to student perceptions of the value of *ChemCAL Online*. These responses to these are summarized in Table 1.

Thinking of using *ChemCAL* at university so far…	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Mean
ChemCAL has given me valuable opportunities for online learning at my own pace	1	4	9	60	26	**4.1**
The step-by-step approach used to explain concepts in *ChemCAL* is an advantage over textbooks	0	3	12	59	26	**4.1**
ChemCAL helps to break up the monotony of reading lecture notes and textbooks in examination revision	1	1	11	58	29	**4.1**
If I miss important information in *ChemCAL*, the choice to go back over it is valuable	1	2	6	57	34	**4.2**

Table 1. Student perceptions of the value of *ChemCAL Online*

Of particular value, according to the data from the post-use questionnaire, was the option for students to test themselves on practice problems. They also found personal feedback on their attempts at the incorporated problems to be very beneficial. A summary of student responses to the two items in the post-use questionnaire that related to feedback appears in Table 2.

Thinking of using *ChemCAL* at university so far…	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Mean
The individual feedback provided by *ChemCAL* has improved my learning	1	14	32	41	12	**3.5**
ChemCAL provides me with useful feedback on my understanding of Chemistry	1	7	24	58	10	**3.7**

Table 2. Student perceptions of feedback received through *ChemCAL*

This data also indicates that students' expectations, gathered in the pre-use questionnaire, that educational technology would provide them with helpful feedback on their progress, had been met.

The timeliness of feedback was also experienced through the ability to check understanding. As one student put it, 'You can be tested straight away'. Most students also appreciated being able to go back and retry after an incorrect answer rather than just being told it was incorrect.

In data from the second focus group interview, students agreed that *ChemCAL* allowed interactive exploration and manipulation of material in ways not possible with traditional media and that this was of particular benefit. A number of students mentioned that they found it difficult to visualise three-dimensional models adequately when using textbooks with two-dimensional representations. The majority of the group agreed that the ability to rotate three-dimensional objects in *ChemCAL* allowed for a better understanding of the models.

Most of the interviewees agreed that *ChemCAL* allowed interactive exploration and manipulation of material in ways not possible with traditional means. When asked about the ability to explore material in ways not possible with other learning mediums, most students stated their learning had benefited from *ChemCAL*'s interactive format; the ability to manipulate variables and revisit steps.

The responses to the post-use questionnaire items related to graphics and interactive features of *ChemCAL Online* are summarized in Table 3.

Thinking of using *ChemCAL* at university so far…	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree	Mean
Using *ChemCAL* means I can manipulate material to help my learning in a way not possible with other means	1	6	27	52	14	**3.7**
The interactivity of *ChemCAL* helps me focus on understanding Chemistry	2	6	16	60	16	**3.8**
The ability to rotate three-dimensional objects in *ChemCAL* allows for better understanding than just using two-dimensional images from classes and textbooks	1	1	7	52	39	**4.3**

Table 3. Student perceptions of *ChemCAL* graphics and interactive features

In terms of possible enhancements, students suggested that example problems should have increasing levels of difficulty (e.g. 'easy', to 'medium', to 'hard'). Some students suggested that the descriptions contained in *ChemCAL* could be too lengthy at times. A dot-point option was suggested.

Students' overall attitude to *Prelabs Online* was overwhelmingly positive. It was unanimously agreed by those interviewed in the focus group that *Prelabs Online* were 'much better' than the paper-based version. They were perceived to be more efficient and as facilitating better quality and more focused learning outcomes than the paper-based predecessor. In particular, students felt that *Prelabs Online* led to a clearer understanding of the concepts associated with laboratory work, prepared them better for the practical aspects of laboratory sessions and gave better feedback. Student comments included:

> With the Prelabs that related to experiments, you learn more and you know what you're doing when you get there.
> The Prelab tell you what to expect.
> Visualisation is easier – you couldn't do that last semester.
> Last semester, you'd do it and forget, now Prelabs explains the question, fits everything together, you understand and don't forget.
> I used to do them at lunch time just before the lab with little care – now I do it properly.
> This way you know ahead of time what will happen – the labs are clearer.
> I enjoy the labs more now because I know what is going on.
> I recognised a reaction!
> When you actually do the prac in the lab, you remember it from the prelab.
> I knew what a piece of measuring equipment was called *and* how to use it.
> We used to get to labs [in first semester] and go 'What's going on?' and no-one would know.
> There's less stress now because we are more familiar with everything before the lab.
> Now if something goes wrong in the lab, we're more likely to understand *why* and not be upset or confused.
> We used to just get a tick or a cross with no explanation.
> Prelabs include explanation and feedback.
> You know straight away whether you understand or not and you can go over things if you don't quite understand.

Students thought the compulsory nature of *Prelabs Online* was good as it meant they were forced to prepare for the laboratories and that this was useful for the reasons outlined above.

Summary

Flexible access and use of high quality learning resources are important criteria for current university students and *ChemCAL Prelabs Online* meets these criteria. However, this analysis of the student experience of using *ChemCAL Prelabs Online* also demonstrates clearly that the product is much more than a convenient, attractive information resource for university learners. Our students expect educational technology to provide them with feedback and these online resources meet these expectations. Further, these students are interested in and enthusiastic about the material and their learning. Their interactive use of this product is contributing to this engagement with their study of chemistry.

Acknowledgements

Matt Coller, with Peter Tregloan, created the *ChemCAL Online* system and programmed many of the interactive resources in the *Online Prelab* materials. Alison Funston and Bob Craig implemented many of the operating screens in the current suite of Prelab modules. Carol Johnston made available the evaluation tools developed for her 2000 survey of students in Economics and Commerce at The University of Melbourne. Richard Scott-Young carried out the statistical analysis of the two student surveys reported in this work. The *ChemCAL Online* and the *Online Prelab* projects were made possible by project grants from The University of Melbourne, Teaching and Learning (Multimedia and Educational Technology) Committee.

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The effectiveness of the Thai traditional teaching in the introductory physics course: A comparison with the US and Australian approaches

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Introduction

In recent years, a substantial and growing body of research in physics education has been involved with identification of student misconceptions especially in the fundamental physics. Misconceptions are ideas or concepts that students have developed, based on their own experiences, which are often in conflict with the physics point of view. For example, many students believe that if an object is in motion, there must be a force acting on it. It is commonly accepted among researchers in this field that such students have failed to develop a Newtonian way of thinking about mechanics, which is the view held by the physics community. (A collection of the important papers in this field can be found in Pfundt and Duit (1994). Researchers have shown that misconceptions are widely shared, the same ones appearing again and again in different groups of students. They have also shown that traditional instruction is relatively ineffective in correcting these misconceptions or in helping students develop a more 'appropriate' way of thinking. (see for example, McDermott (1990)).

In the last decade or so, much work has been done on developing special diagnostic tests to uncover misconceptions and to investigate students' understanding of physics concepts — see for example, Hestenes (1998). These tests usually consist of multiple choice questions in which the correct answer is hidden among very attractive wrong answers. These wrong answers are, in fact, constructed from common misconceptions identified by earlier researchers. Among the best known of the physics tests in the area of dynamics and kinematics are: the Force Concept Inventory (Hestenes, Wells and Swackhamer, 1992); the Test for Understanding Graphs in Kinematics (Beichner, 1994); and the Force and Motion Conceptual Evaluation (FMCE), designed by Sokoloff and Thornton (1998). Much effort within the Physics Education Research community has gone into evaluating these tests, both by themselves and in relation to one another (see for example, Huffman and Heller (1995)).

Administration of these standardized tests to many groups of students (mostly within the USA) has led researchers to the conclusion that (1) in general, the understanding of concepts in mechanics by introductory physics students is quite poor, and (2) that this low level of understanding is not much improved by the standard teaching given in most universities — so long as the teaching is 'traditional', i.e. consists mainly of lectures and laboratories. On the other hand, where innovative teaching methods, usually referred to as 'interactive-engagement' methods, are used, considerable gains can be achieved. For a definitive review of all these findings see Hake (1998).

The current authors are interested in whether these same general findings can be extrapolated to other cultures, or whether they are only really applicable within the USA. We focus attention on one of the above standardized tests, the FMCE, because the originators of that test have also developed a particular interactive-engagement teaching technique which targets the same concepts as the test addresses. Reports of the testing of their own students can be briefly summarized thus. (1) The great majority of these students entered a university without a correct, or Newtonian, point of view on kinematics and dynamics, and (2) after instruction by the new teaching method, some 80-

90% of their students were able to complete the FMCE successfully (a much higher fraction than in parallel, traditionally taught classes). See Sokoloff and Thornton (1997) for details. Some teachers in other institutions have used the same methods and report similar results (Cummings et al., 1999).

In Australia, Johnston and Millar (2000) did the same experiment and found comparable results, with one major difference. When the test was administered to introductory physics students *before* any instruction had taken place, the students' understanding of the concepts (as measured by the FMCE) was markedly higher than for US students. Since the universities involved in all these trials seemed to be much the same as regards entrance requirements and so on, this finding is interesting, though its significance is not clear.

For many reasons therefore, it would seem important to ask whether these findings are valid only for Western educational systems, or whether they are also likely to apply to, for example, the educational system in South East Asia. As a first step in answering this question it was decided to test students in a non-Western context in order to study their pre-university level of understanding and the effectiveness of traditional teaching. The same FMCE test was given, before and after instruction, to 1300 physics first year students at Mahidol University in Bangkok, Thailand.

The Force and Motion Conceptual Evaluation (FMCE)

The FMCE is a research-based multiple choice assessment instrument that was designed to probe a conceptual understanding of Newtonian mechanics. It consists of 43 questions, which are divided into 8 sets. Thornton and Sokoloff (1998) focused on the following four sets of the test.

Set 1: Natural Language Evaluation (questions 1, 2, 3, 4 and 7). This set consists of five force-sled questions, asking students to relate a force to various motions of the sled. All the questions make no reference to graph or coordinate system. The questions in this set are as follow.

'Choose the force which would keep the sled moving as described.

1. Which force would keep the sled moving toward the right and speed up at a steady rate (constant acceleration)?
2. Which force would keep the sled moving toward the right at a steady velocity?
3. The sled is moving toward the right. Which force would slow it down at a steady rate (constant acceleration)?
4. Which force would keep the sled moving toward the left and speed up at a steady rate (constant acceleration)?
7. The sled is moving toward the left. Which force would slow it down at a steady rate (constant acceleration)?'

Set 2: Graphical Evaluation (questions 14, 16, 17, 18, 19, 20 and 21). This set uses graphical representation in the answers and does not explicitly describe the force that is acting to an object. All questions are asked in the same way as those in set 1, so they measure the same concepts in physics.

Set 3: Coin Toss (questions 11, 12 and 13). This set of three questions asks students to select a force acting on the coin tossed straight up into the air. The questions in this set are as follow.

'Indicate the force acting on the coin for each of the cases described below.

11. The coin is moving upward after it is released.
12. The coin is at its highest point.
13. The coin is moving downward.'

Set 4: Cart on Ramp (questions 8, 9 and 10). This set of three questions is similar to set 3 except that the situation is changed from a coin tossed into the air to a cart pushed and released up the ramp.

Full detail of the test as well as deeper discussion and analysis of the test can be seen in Thornton and Sokoloff (1998).

The translation

English is not the native language of Thai people. Many Thai students have problems with English questions. Therefore, it is impossible to use the FMCE test with Thai students without translation. The translation was carefully done by an experienced Thai physics professor at Mahidol University. He has done many translations of English physics problems into Thai ones. The Thai version of the test uses technical terms understandable by first year students. Each question was translated in the way that all its original meanings are kept and no further explanations are given. The translation into Thai was validated by 20 academic staff and graduate students in the physics department at Mahidol University. They were asked to do both Thai and English versions of the test. The Thai test was given first and then the English test. Therefore, the staff and students had no chance to translate the test on their own. With minor adjustment of the translation, all of the staff and students arrived at the same answers for each question in both Thai and English tests. In other words, if a person made a mistake in one of the questions in the Thai test, he also made the same mistake in that particular question in the English test.

The experiment

We have done the test at Mahidol University, which is one of the best universities in Thailand, especially in the fields of science and medical science. The first year calculus-based physics course at Mahidol University enrols around 1300 students. The students major in medical science, engineering and pure science. They were generally divided into 6 classes. Each class had roughly 200 students and was taught by different lecturers. The physics course in the first semester consists of four topics: Mechanics, Waves, Thermodynamics and Electromagnetism. The 12 hours of Mechanics take 6 weeks of lectures.

The students were asked to do the FMCE test during the first week of the first semester before the traditional instruction was given. The Mechanics lecture lasted 6 weeks and covered dynamics, kinematics, work, energy and rotation. The traditional instruction includes standard lectures, homework problems, and quizzes. The students also enrolled in a separate course of physics laboratories with weekly experiments. The students were told that test results had no effect on their grades, but they would get a few points in reward for doing the test. Three weeks after the end of the Mechanics lecture, which is also one week after the regular mid-semester examination, the students were given the same test again.

Results and discussions

The pre-test results of the experiment are shown in Figure 1 in which student responses are reported for four sets of questions.

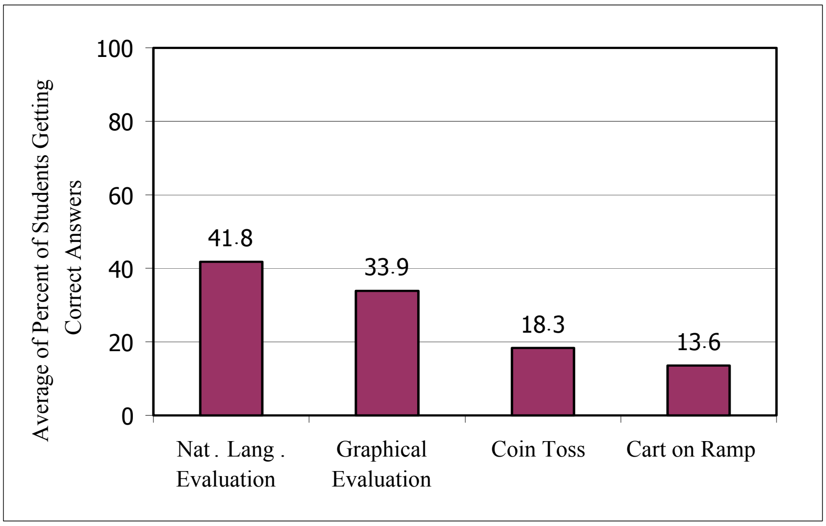

Figure 1. The percentage of correct responses in the pre-test from 1300 students at Mahidol University

The first point to be noted is that around 40% of the students answered the dynamics questions in set 1, the natural language evaluation, in the ways that are consistent with a Newtonian view of the world. The graphical evaluation that roughly asks the same questions, yields lower percentage. This is possible owing to the lack of practice on the graphical part of dynamics for Thai students.

For the coin toss and the cart on ramp sets of questions, we follow Thornton and Sokoloff (1998) by considering that students have the Newtonian point of view only when all three questions in each set are answered correctly. The results of these two sets (see Figure 1) show that less than 20% of the students have the Newtonian point of view.

For detail of the distribution of marks on selected test items, we choose to show percentage of students getting the correct answer in each question of set 1 and set 3. This is shown in Figure 2.

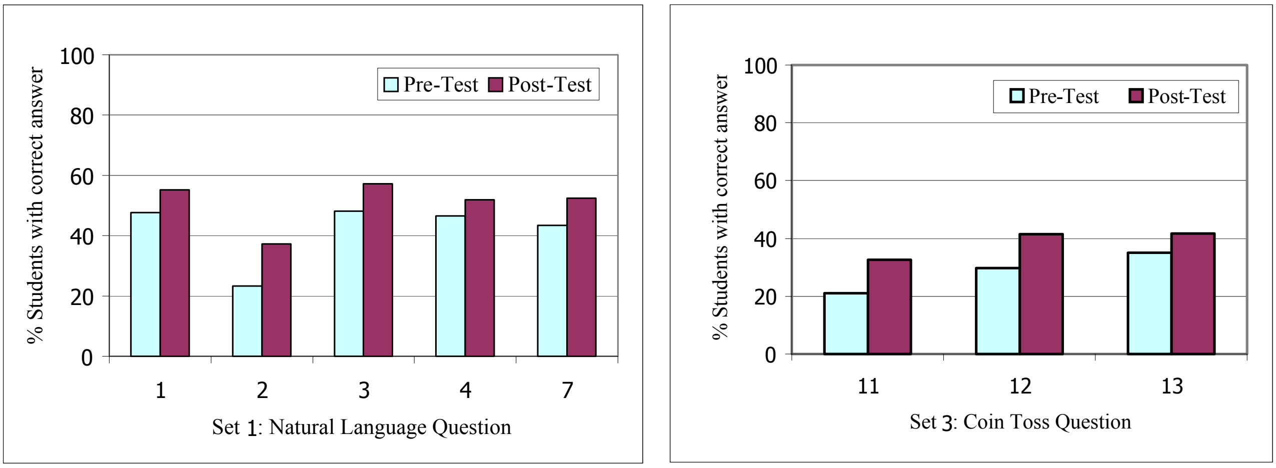

Figure 2. Pre-test and post-test percentages of correct responses to questions in set 1 and set 3

Low scores in question 2 of set 1, both in pre- and post-tests, indicate students' misconception in relating force with motion even when the sled is moving at constant velocity. Relatively low scores are also found in all questions of set 3, especially question 11. The changes before and after traditional instruction averaged about 9.0% and 9.8% for set 1 and set 3 questions, respectively. Such low improvement on these questions may be due to the wrong assumption of the teacher that students have already had the right concept about force and motion before entering the university. (The teacher was not provided with the pre-test results before giving the lecture). The results also indicate that most of the students still use their own concepts and do not accept the Newtonian point of view. They somehow relate the direction of force with the direction of motion.

Figure 3 shows the student understanding before and after traditional instruction for all sets of questions. It is clear that the lecture has small effect on student understanding since the total change before and after traditional instruction is about 9.7% in average. This is quite a low gain after the traditional instruction was given although there is a big room for improvement due to the low pre-test scores.

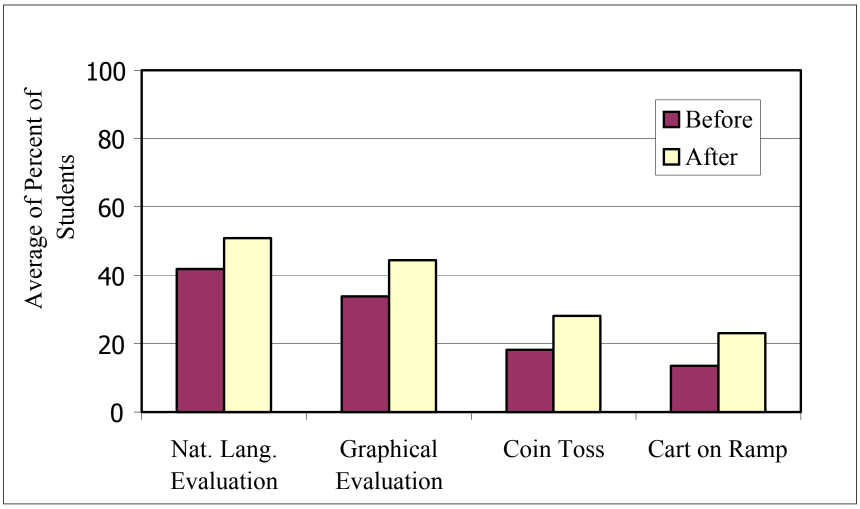

Figure 3. Comparison of the percentage of correct responses before and after traditional instruction at Mahidol University

Comparison of the pre-test scores of Thai, Australian (Johnston and Millar, 2000) and US (Thornton and Sokoloff, 1998) students on the same sets of questions is shown in Figure 4. All four sets of question show the same trend. The pre-test scores of Thai students are between the US and Australian. The average of the pre-test scores for US, Thai and Australian are 9%, 27% and 49% respectively.

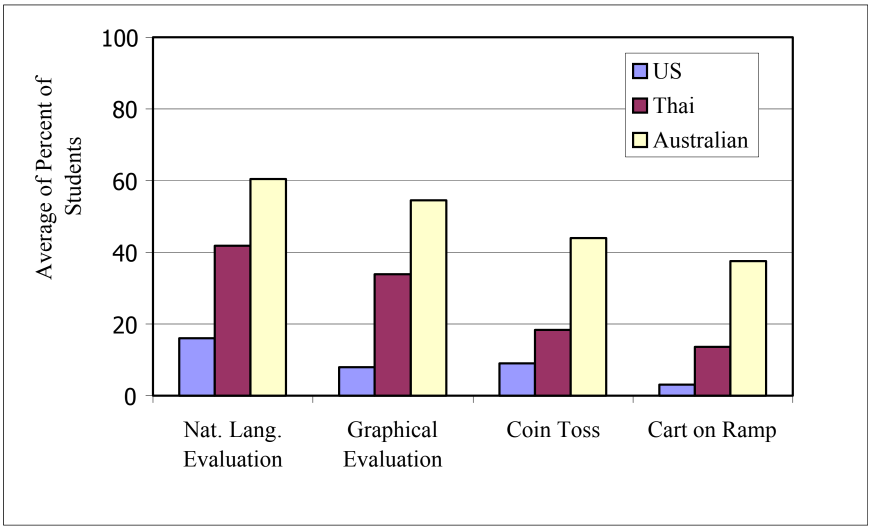

Figure 4. Pre-test percentage of correct responses to questions in four sets, as published by Thornton and Sokoloff (US), Johnston and Millar (Australian) and at Mahidol University (Thai)

A comparison of the gains from the three different contexts is shown in Figure 5. In all cases the student gain was quite low. In fact, the averaged gains are almost the same. They are 8.0%, 9.7%, and 10.1% for US, Thai and Australian students, respectively. The three contexts have similar gain despite the fact that their pre-test scores are quite different. These gains confirm the worldwide-accepted conclusion that traditional instruction is ineffective in teaching physics concepts and in changing misconceptions.

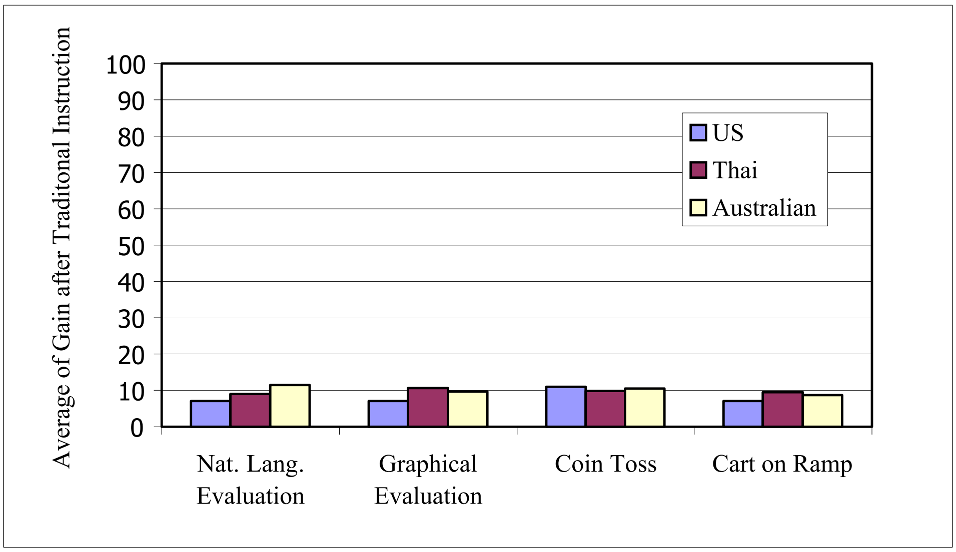

Figure 5. The percentage of gains after the traditional instruction on questions in four sets, as published by Thornton and Sokoloff (US), Johnston and Millar (Australian) and at Mahidol University (Thai)

Conclusion

We have done the conceptual evaluation test with around 1300 students in a Thai university. The result from the pre-test shows that a few students entering a university understand force and motion from the Newtonian point of view. After a semester of traditional instruction the improvement in performance is found to be quite poor. There was an increase of only 10% from the pre-test scores. Such results have also been found in universities and colleges in the US and in Australia, as reported in the literature (Thornton and Sokoloff, 1998; Johnston and Millar, 2000). The findings of this project therefore support the widely held view that traditional teaching is relatively ineffective in helping students to learn physics concepts and in changing misconceptions. It is also interesting that the average of the pre-test scores in the Thai context is 27% which is lower than for Australian students but higher than for US students. Again the significance of this is not clear and calls for further investigation.

We believe that it is possible to conclude that the 10% improvement points to the ineffectiveness of traditional teaching on mechanics, in Thailand as in the USA and Australia. The second stage of this project must therefore be to test whether a significant improvement in understanding (as measured by the MFCE) can be achieved by replacing traditional teaching strategies with more interactive learning ones (see, for example, Sokoloff and Thornton (1997) and Johnston and Millar (2000)).

Acknowledgements
The authors would like to thank Assistant Professor Piyapong Sithikong at the Department of Physics, Faculty of Science, Mahidol University, who helped translate the FMCE paper. The test materials and the funding for a trip to present this paper at the UniServe Science Conference 2002 are supported by the Faculty of Science, Mahidol University.

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Getting bench scientists to the workbench

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Introduction

In the Australian University sector today, the separation of the 'world of work' from formal education is becoming more artificial. Since the mid-eighties, the voices of Government and Employer bodies have combined to demand more workplace-relevant skills and attributes from university graduates (ACNielson, 1998, 1999; NBEET, 1992; Tomas, 1997). Variously referred to as generic skills, capabilities, key skills or graduate attributes, these include literacy, numeracy, computer skills, time management, written and oral communication, interpersonal skills, teamwork, leadership, creativity and problem solving (ACNielson, 1999) amongst others. Universities have responded, to a greater or lesser extent, by revisiting their curricula with the aim of integrating the development of such work-relevant skills and capabilities into their degree programs. A related response has been to establish or enhance already established industry-university linkages through research partnerships and work placement programs. A work integrated learning (WIL) program (cooperative education, work experience, internship) has the potential to assist students to develop these skills, and more. Student motivation, classroom learning and course completion are enhanced when a WIL program is implemented effectively, whilst at the same time students develop an awareness of the 'world of work', confirm or redirect career decision-making, and improve their job opportunities (NCCE, 2002). This paper explores the issues that need to be addressed in the sciences, before an effective WIL program can be developed so that all partners in the process can achieve useful outcomes.

WIL in the sciences

Faculties or disciplines that have firm ties to a profession, such as Law, Nursing, Medicine, and Education, traditionally have work placements as part of the learning experience, however, there is no reason why all university students should not have the opportunity of experiencing some form of work in their undergraduate program. In 1998, nearly 60% of university courses had some element of work experience, and learning of this type accounted for between 1/8 and 1/4 of total marks (Martin, 1998). Universities with strong industry ties, most notably the previous 'Institutes of Technology', are well placed to expand their programs with regard to WIL. Their ties with industry partners are strong, and a culture of commitment to work experience already exists amongst staff and students. Such understanding of, or support for WIL is also present in the professional degrees mentioned earlier, but how much of this commitment to, and understanding of WIL is present in the more traditional university offerings that include the bench, pure and 'enabling sciences' (such as chemistry, mathematics and physics) is open to question.

There are various forms of WIL already integrated into a small number of science programs in universities around the world, and the range and variation are represented in Table 1. Specific models include:

- **cooperative programs** – work experience integrated into the overall curriculum;
- **cooperative Education for Enterprise Development (CEED) programs** – which are university-industry partnerships assisting with the training of students in technological fields as they undertake industry-relevant projects (based on a program originally developed at RMIT); and
- **fieldwork** – from 1 to 4 days a week with the employer/agency, for a defined period.

University	Characteristics
University of British Columbia, Canada *BSc*	• 5 year cooperative education program (normally 4 years) – all disciplines • all basic subjects studied prior to work placement • students selected on basis of academic performance, enthusiasm and motivation • students hired and paid for their work • e.g. Biochemistry and Molecular Biology – terms 1 to 6 on campus; summer vacation and following year in work placement; terms 7 and 8 on campus
University of Waikato, NZ *BSc (Technology)*	• 4 year degree – BSc + 2 Management Papers (units of study) • 12 months paid work experience – 3 months at end of second year; 9 months at end of third year, return semester 2 in fourth year
The University of Adelaide, Australia *BSc (Physics)*	• *EPIC program* – Education in Physics with Industrial Cooperation: 4year degree • students apply after second year, with a credit average across the 2 years • paid work experience for 4-5 months: semester 2 year 3 plus semester 1 year 4 in work placement, return semester 2 • project jointly agreed to by academic staff and employer
The University of Adelaide, Australia *BSc (Honours)*	• *CEED program* – projects in conjunction with external organization • students apply in semester 1 of year preceding honours, if accepted students take a Science Industry Practicum subject in second semester as preparation • 8 weeks in summer vacation period with some financial recompense

Table 1. Examples of models of WIL in science and applied science programs within universities

Though the structure of these work experience programs differs, they do exhibit some commonalities – many of them are only available to the more able students who are then commonly paid whilst undertaking the WIL program. The benefits or otherwise of models such as these are discussed elsewhere (Martin, 1997; Davies and Hase, 1994), but the extent to which WIL science programs are ‘quality’ programs is not known. A careful consideration of each program, with regard to issues of quality, and the extent to which the rest of the curriculum is structured in order to prepare students to integrate the experience with the rest of their education experience (see later), is necessary before one or other variation of WIL could be considered more effective than another.

If curriculum change incorporating WIL is to become more extensive in the sciences in Australia, there could be no more opportune time for it to happen than now. The last two decades have seen a continued shrinkage in government funding for universities, which, coupled with rising HECS fees and student debt, contributes to student disinterest in the pure science disciplines, which attract high HECS (Level 2) and are potentially low income-generating careers. The sciences are faced with a fight for survival (Senate Report, 2001). The Government is demanding that universities become more responsive to society’s needs, more relevant and ‘applied’ in nature. The quiet acquiescence of higher education to the corporate world has, however, raised considerable concern amongst educators in recent decades (Kolb, 1984; Boyer, 1987; Dewey as cited in Saltmarsh, 1992). Regardless of the government agenda or the debate it generated, there are good reasons why the sciences should consider integrating some experience of work into the curriculum.

The benefits of work experience

The benefits of work experience, as documented in a comprehensive study from the UK (Harvey, Geall and Moon, 1998), are outlined in Table 2. In this study, written feedback or interview data was collected from over 100 university academics, placement coordinators and employers, and used in conjunction with an extensive critique of the literature and re-analysis of empirical data collected from students by the Centre for Research in Quality in the UK. Though the benefits are impressive, the *‘experience of work should not be regarded as something that is intrinsically beneficial: something that is somehow “good for the soul”’* (Harvey, Geall and Moon, 1998, chapter 2, page 1).

The establishment of an effective WIL program has implications for the development of content and skills in science courses, and the attitudes and understandings of academics, students and employers.

Student perspective	Employer perspective	Academic perspective
Working in a setting in which to put theory into practice *Developing an awareness of work-place culture* *An appreciation of the fluidity of a rapidly changing world of work* *An opportunity to develop a range of personal attributes* *The development of key interactive attributes (team-working, interpersonal skills and communication)* *Short-term financial benefits* *Enhanced employment prospects and the potential of commanding higher wages when starting employment after graduation* *Assistance in developing career strategies* *Working in another culture, learning other languages and contributing to the global community* *Encourages course completion*	*Extra workers at low cost* *The setting up of a new project* *The completion of specific tasks* *The opportunity to give a potential recruit a trial without obligation* *Using student's reflection on work as a recruitment criterion* *A pool of potential recruits with an awareness of workplace culture* *An injection of new ideas* *Developing links with higher education institutions* *Staff development opportunities that arise from employees mentoring students* *Improves workplace diversity* *Increases retention rates of employees hired through cooperative programs* *Enhances human resource flexibility within effective short-term employees*	*The opportunity for students to see their subject area in practice* *The satisfaction of seeing students develop and mature* *The enhancement of students' skills* *The establishment of links with a wider range of employers* *Using employer contacts to ensure that their teaching is up-to-date* *Using links to encourage employers to participate on course validation panels, participate in seminars* *The tailoring of innovative or more work experiences through collaboration with past employers of placement students* *Developing their expertise in assessment methods by working with employers who have experience in assessing 'employability skills'* *Enhances public support for the institution* *Access to state of the art equipment*

Table 2. Benefits of work experience – student, employer and academic perspectives (adapted from Harvey, Geall and Moon, 1998)

Harvey, Geall and Moon (1998) stress that in order for learning to come from the work experience, the program needs to address crucial areas (Table 3), including it being a **meaningful experience**, **intentional, organized** and **accredited**. An Australian study (Martin, 1997), in which eight university courses in four vocational areas (health science, engineering, business and social work) were investigated by way of interview and questionnaire data collected from students, academics and employers, supports these findings. The Martin study is of interest to science educators as it cites two Case Studies as exemplars of effective WIL programs, courses from Victorian Universities in Medical Laboratory Science and Electronic Engineering. Both include a variety of characteristics, which cohere with the framework suggested by Harvey, Geall and Moon (1998). The characteristics that make the courses effective learning experiences include:

- participating companies develop a tender for students to address a particular issue or problem;
- students often work in teams, and are always supervised by a member of academic staff, as they develop and submit a proposal which includes a statement addressing how they will develop as professionals through the exercise, as well as how they will address the problem;
- students submitting successful proposals work for a full year on the problem together with workplace and academic supervisors;
- the program involves regular reporting and monitoring of progress and problems; and
- each program is assessed and accredited by the university.

The Medical Laboratory Science program also requires students to maintain a journal, which serves as the basis for regular reflection and discussion with both workplace and academic supervisors.

Meaningful Experience – for all stakeholders	• *For academics* – linked to subject specialisms • *For employers* – enabling students to make a positive contribution, and gain an appreciation of the organization • *For students* – to provide a practical context for their study and to develop the skills and maturity they need for the workplace

Intentional and Recognized	• Learning is 'deliberate' (Tough, 1971) with specific goals and identifiable learning outcomes
	• The experience:
	  • is well organized, planned and prepared
	  • has ongoing and built-in reflection about what and how they are learning

Reflection and Articulation	• Students need to be able to articulate their learning – to reflect on it, identify what has been learned, and critically review their progress both at regular intervals and retrospectively
Assessment and Accreditation	• Assessment shapes students' experience learning – to be valued, it should be assessed • To be taken seriously, the experience should be accredited

Quality Issues	• The *quality process* is tied to its relevance, structure, organization and intentionality
	• Employers are committed to it, and aware of its implications, involved in the planning and provide adequate support, training and workplace supervision
	• Academics have ongoing responsibility to monitor and support the students whilst on work placement, including:
	  • prior induction and briefing of all concerned
	  • facilitation of ongoing reflection
	  • debriefing and identification of outcomes

Table 3. The crucial areas requiring consideration for WIL in undergraduate programs (adapted from Harvey, Geall and Moon, 1998)

Integrating WIL into science programs 'from scratch'

Issues that need to be considered when implementing WIL – problems to avoid, structures and resources to develop, are too numerous to discuss in this paper, and are better dealt with elsewhere (Davies and Hase, 1994; Gardiner and Singh, 1991; Martin, 1997), however what it means for those interested in developing WIL, warrants further exploration. It is usually the institution's responsibility for accrediting the work placement experience, hence much of the responsibility for developing and organizing the program will fall on the shoulders of academics involved in it. It is essential that academics understand its goals and are committed to developing, implementing and monitoring the program. There are clear links between the way academics think about learning in work placements, how they plan and support the placements, their student's perceptions of their own learning during the experience, and the satisfaction they and their employers feel with the placement (Martin, 1997). Staff who view workplace learning as in need of careful planning and collaboration with employers are more likely to produce students and employers who perceive considerable benefits from the work experience. The study also suggests that the opposite is true – if it is assumed students will learn simply because they are in the workplace, and hence there is little attention paid to learning outcomes and supervision, the least effective learning outcomes will ensue (Martin, 1997). So how do proponents of WIL engage academic scientists with their notions? Is it simply a matter of elucidating its benefits, or are the issues more complex than that?

It is not unusual for traditional science courses to be highly structured and teacher-directed, with infrequent opportunities for student interaction and discussion at a high cognitive level. Learners of science at university are rarely given the opportunity to reflect on their own learning needs and skills development, or negotiate learning contracts to enable them to pursue learning of real personal interest and relevance to them. Without a commitment to learner-centred pedagogies whereby students' concerns, interests and problems leading to their active engagement with the culture of scientific thinking and doing (Gardiner and Singh, 1991) is the starting point, combined with a critical reflection upon the pedagogical practices and assessment procedures present in the existing curriculum, there is little base from which to move into the world of work.

There is abundant research literature to assist academics in their thinking about the curriculum. The work of Kolb (1984) in experiential learning, taking the learner from ‘knowing what’ to ‘knowing how’ (through the four stages of learning – concrete experience, reflective observation, abstract conceptualization and active experimentation), provides a pathway for a conceptualization of the curriculum as ‘delivered’ on-campus through to the integration of WIL into the learning program. Boyer (1990) initiated the process of reconceptualizing scholarship in academia, moving away from one dominated by the scholarship of **Discovery**, towards one in which other forms of scholarship – **Application**, (whereby theory and practice in the scholar’s special field of knowledge are connected), **Integration**, (making connections across the fields, disciplines and professions) and **Teaching** (wherein the work of academics becomes significant only as it is understood by others), are valued and rewarded. This too provides academics with a framework within which to consider the links between their own research, teaching, community outreach and the professional world. In order to address such complex curricular issues and understandings however, it may be necessary for academics to first reflect upon their own conceptions of teaching and learning.

A study by Prosser, Trigwell and Taylor (1994) that looked at how 24 university science teachers view their role as teachers, identified 6 conceptions of teaching:

Conception A: Teaching as transmitting concepts of the syllabus;
Conception B: Teaching as transmitting the teacher’s knowledge;
Conception C: Teaching as helping students acquire concepts of the syllabus;
Conception D: Teaching as helping students acquire teachers’ knowledge;
Conception E: Teaching as helping students develop conceptions; and
Conception E: Teaching as helping students change conceptions.

The earlier conceptions (A-D) focus only on the teacher or context, with little focus on students, whilst the more complete understandings consider the students as centrally important. The study also found there to be a strong empirical relation between university science teachers’ conceptions of teaching and their conceptions of the learning undertaken by their students. Those who hold conceptions of teaching as being the transmission of knowledge, talk about learning as being about students accumulating more information, rather than developing and changing their conceptions and understandings (Prosser, Trigwell and Taylor, 1994). Without coming to terms with our own views of teaching and what it means for students to learn, it is hard to understand why it is necessary, let alone to actually change teaching practices from teacher-directed to learner-centred pedagogies. Academics with the less sophisticated understanding of teaching would find it difficult to engage with the philosophy of WIL, at least at the level required to implement an effective program.

Future directions

It is possible to integrate quality WIL programs into science curricula, however to do so requires that the understanding of individual teachers, employers, students, and institutional bureaucrats be challenged, as the older paradigms of education, training and work are dispelled. A WIL program that is contextualised in the classroom by teachers who can facilitate student comprehension of the intellectual basis and meaning of the work experience, will be an experiential program that enhances student learning (Katula and Threnhauser, 1999). Participating employers and academics need to engage in a ‘transactional dialogue’ (Brookfield, 1986) aimed at understanding each other’s workplace culture and dominant language, and sharing differing interpretations and viewpoints, in order that a common vision and real partnership can develop (Davies and Hase, 1994). As far as possible, there should be shared curriculum development and program delivery using methods suited to the needs of the workplace and reflecting the distinctive strengths of the WIL partners (Davies and Hase, 1994). Students will certainly take their lead from the academics that teach them, the learning environment within which they are immersed and the mentoring they receive from their supervisor and colleagues in the workplace. University policy makers must support teaching staff and their workplace partners, as they grapple with complex curricula issues and understandings, through the provision of specialist expertise, professional development and funding. University workload formulae and promotions structures should value and reward academics engaging in the development, implementation and support of WIL programs, or similar changes which require a substantive paradigm shift. The success or otherwise of such programs lies in the commitment and involvement of academic staff (Martin, 1997), and the establishment of an effective partnership between the learner, the university and the employer wherein the desires and perspectives of each stakeholder are reconciled (Foster and Stephenson, 1998).

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Using online discussion in teaching undergraduate psychology

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Introduction

Enthusiastic support for the use of online communication in teaching has led to one of the fastest growing uses of technology in education, particularly in open learning and distance education (Bates, 1995). Many of the applications discussed in the literature rely on asynchronous, text-based computer conferencing, hereafter referred to as *online discussion groups*. This emphasis probably reflects the uptake of a technology with which many are already familiar (based on email), that affords flexibility for people separated by time and place, and is currently more reliable and accessible (compared to, for example, audio or video-conferencing). One aim of the paper is to illustrate how particular models relevant to the use of online discussion in teaching and learning can be used to inform practice in terms of identifying the purpose of the online interaction and the management of this interaction (e.g. the role of the moderator). These issues are discussed in the context of using online discussion in an undergraduate psychology subject, and the second part of the paper reports on the results of an evaluation of the effectiveness of this discussion group as a learning resource for students.

Ways of using online discussion

Student-student and student-teacher interaction is a highly valued part of the university education experience. This value reflects a common theme in contemporary theories of education which view learning as the active process of constructing knowledge (e.g. Duffy and Cunningham, 1996) that is supported by dialogue (e.g. Laurillard, 1993). The need to instigate this dialogue ‘online’ reflects the global phenomenon of ‘flexible learning’ that is changing the way universities deliver their courses. The push for flexibility is seen as responding to market needs of mature-aged, life-long learners with work and family commitments (Bates, 1995). This flexibility affords the learner choice about not only place and time, but also in some instances level and timing of entry, curriculum and pace of learning (e.g. Nikolova and Collis, 1998).

There can be, however, a certain degree of tension between wanting to offer flexibility and being able to include dialogue as part of the learning experience. This tension can be usefully viewed in terms of the idea of ‘transactional distance’, referring to the distance between teacher and learner that is bounded by the degree of structure in the course materials and the opportunity for dialogue (Moore, 1990, cited in McIsaac and Gunawardena, 1996). Mason (1998) proposes a framework for considering online courses, identifying three course models that could also be seen as varying along a continuum of transactional distance. The greatest ‘distance’ will be found in the type of course which Mason refers to as the ‘content + support’ model. Here there is a clear division between the course materials that students are working on (typically print-based or web-based) and the availability of support by tutors who are unlikely to have been involved in the development of the content. In this situation, online discussion may be used to support interaction with tutors to discuss issues arising from set learning materials, with relatively little of the students’ time spent online. This type of course is likely to offer the most flexibility in terms of time and place of learning. In contrast, other courses place greater emphasis on the role of student-student and student-teacher interaction as part of the curriculum. In Mason’s terms, the ‘wrap-around’ model is based around a select set of resources, with interaction as an important part of encouraging students’ interpretation of material. In entirely ‘integrated’ courses, students work on collaborative projects, and the substance of the course is based on small group work. In both the integrated and wrap-around models, the opportunity for dialogue becomes a core component of the learning activities, and may involve the small group online discussion. However, in these cases, the flexibility offered by an online discussion forum may be compromised by requirements to spend considerable amounts of time online, and the need for a critical mass of students to be working at the same pace. In sum, depending on how important flexibility is to the students and teachers, and the degree of structure in the learning experience, the use of online discussion to support interaction between teachers and learners will differ. Mason's framework offers one way of assessing how the opportunity for online interaction might best be integrated into a given learning context.

Using online discussion in the undergraduate psychology context

The introduction of online discussion in an undergraduate psychology context was part of a move toward more flexible delivery. One of the challenges was to determine how online discussion could be used as a useful resource in subjects with large enrolments and a diverse student cohort. The second year psychology subject that is the focus of this paper, is taught on-campus (lectures plus laboratories) and by distance education (print-based study materials and laboratory 'weekend school'). Lecture summaries and online audio of lectures (for some components) are available for all students via the Web. The laboratory program includes some face-to-face classes and some flexible laboratory activities which students complete at a time and place of their convenience. It was decided to set up one online discussion group dedicated to answering student questions about the academic content of the subject, in particular the laboratory program. One academic was responsible for replying to student messages as part of their teaching duties. Within this context, the potential for the use of online discussion was seen to be more closely aligned with Mason's (1998) 'content + support' model, described above. The use of the online discussion was seen as likely to be unstructured dialogue between a tutor (academic moderator) and students about the course content, maximising the flexibility in terms of pace and timing of the interaction. In this subject, the flexibility of the environment is important in accommodating both on-campus and distance education students. These groups of students are likely to be working at different paces (e.g. weekly on-campus laboratories versus one weekend school), and to different assessment schedules. The percentage of time spent online by students was seen as a minimal component of the total learning activities, and participation in the online discussion was voluntary and did not contribute to assessment.

Facilitating online discussion

The role of the moderator in the online discussion depends on the purpose and audience of the forum. Given the large enrolment of students in this psychology subject (approximately 600), the use of the online discussion group corresponds to Salmon's (2000) description of a large-scale course community. In this situation, Salmon suggests accessing and responding to the group on a daily basis, and using a team of moderators to facilitate course team involvement. Although desirable, this was not possible in the current context, where one academic was responsible for moderating the forum. However, help and advice from relevant others was sought in response to specific questions (e.g. from the subject coordinator or technical advisers). The level of responsiveness was committed at a response within 24 hours, where possible.

In the psychology context, the use of the online discussion group was aligned with 'content + support' for a large group of students, where the focus of the 'discussion' is likely to be on question and answer between the tutor and student. As such, the likely moderator's role does not fit well with the more typical view of the moderator in educational settings, such as Salmon's (2000) five-step model. This model begins with an access and motivation phase (technical problems and welcome), followed by a phase of encouraging online socialization, before participants begin to focus on information exchange in the third phase. The later stages involve the facilitation of discussion to support knowledge construction and finally reflection as participants take on responsibility for the discussion. In the psychology discussion forum, the initial phase remains important, although there is much less emphasis on online socialization (in fact, providing a separate discussion group for that purpose discourages this). Instead, the main focus is likely to be on information exchange, but this dialogue will occur between tutor and student rather than between students themselves; and there will be less emphasis on the higher stages of development identified by Salmon.

Despite these differences, the importance of facilitating interaction and providing a comfortable atmosphere for participants remains an essential part of developing an effective learning environment. As more teachers go 'online' there is a steadily increasing number of 'how to' guides for moderating online discussion groups (e.g. Collins and Berge, 1996; Harasim et al., 1995; Paulsen, 1995; Salmon, 2000; as well as various authors at http://www.emoderators.com/). Summarizing these guidelines is beyond the scope of this paper; however, it is worth noting that the recommended techniques respond to a number of unique aspects of using text-based, asynchronous communication. Some of these peculiarities include the absence of non-verbal cues and obvious 'turn-taking', time delays between responses that can contribute to anxiety and feelings of isolation (Feenberg, 1989; McIsaac et al., 1999), the need for an informal 'say-writing' style and specific rules such as 'netiquette'. The moderator guidelines also highlight the importance of training, the 'welcome' message, use of reinforcement and encouragement, and techniques for facilitating student-to-student interaction.

Results and discussion

An evaluation of the discussion group was undertaken at the end of the teaching semester, and included an analysis of the transcript from the online discussion for this subject, and student responses to a short questionnaire. (Note: a similar online discussion group was also part of this subject in the previous year, but this level of evaluation was not conducted on the first offering.) In the last week of teaching, the questionnaire was sent to all distance education students and was administered during the review lecture for on-campus students. The evaluation included questions about access and previous experience with online discussion. If students did access the discussion group, they were asked questions about their perceptions of the usefulness of the forum and the effectiveness of the moderator (not reported here). Most of the questions were structured, closed questions to facilitate analysis. A final question eliciting more open-ended comment was also included. A summary of the response rate to the questionnaire for the different student cohorts is given in Table 1. The overall response rate was 25% (N = 152), which is quite low, and even lower in the areas of distance education and at the rural campus. However, note that lectures were not compulsory and the last week of semester is always a very busy time for students. Also, the return of the questionnaire for distance education students required the extra step of postage.

Student cohort	Accessed the discussion group?		Total responses	Number enrolled
	YES	NO		
Metropolitan campus 1	40 (40%)	60	100 (27%)	368
Metropolitan campus 2	12 (34%)	23	35 (29%)	120
Rural campus	3 (42%)	4	7 (17%)	42
Distance education	7 (70%)	3	10 (13%)	79
Total	**62 (41%)**	**90**	**152 (25%)**	**609**

Table 1. Summary of responses to the question about access to the subject discussion group as a function of total number of responses and the number of students enrolled for each cohort of students

Users of the psychology discussion group

A count of the number of messages in the transcript of the discussion forum showed that a total of 398 messages were posted over 15 weeks of the semester (beginning Week 1). Approximately 13% (N = 81) of students enrolled in the subject posted a message to the discussion group. Almost half of these students (47%) posted only one message, with a further 38% posting between two and four messages. Of the sample that completed the questionnaire, 16% (N = 25) of students reported sending a message to the discussion group (which is slightly more than the 13% of the total number of students enrolled in the subject who posted to the discussion group). Although the number of students actually posting to the group was relatively small, the responses to the questionnaire showed that, on average, approximately 40% of the sample accessed the discussion group (see Table 1). The percentage was much higher for distance education students (70%), but this is likely to reflect a bias toward students who did use the discussion group finding the subject of the questionnaire more relevant and therefore being more likely to respond. The majority of students who indicated they did access the discussion group nominated their frequency of access at less than 5 times (N = 30); 13 accessed up to 10 times; and 5 students up to 20 times. A small group of 14 students were very frequent users, accessing the group more than 20 times. It is difficult to know how to interpret these results as the data could indicate frequent access over a short period, or regular and ongoing access throughout the semester.

Purpose of the psychology discussion group

Of the total number of messages posted to the discussion group (N = 398), the moderator posted 43% of the messages. An analysis of the content of the discussion forum shows that the moderator generated only seven of the 147 subject threads, and most of these were in the very early stages of the forum. The subject of the student-generated threads was categorized into five topic areas, and the frequency of each topic area was counted. The results indicate that the content of the discussion was primarily about the laboratory assignments (55%), with questions about subject requirements contributing about 25% (e.g. due dates, access to course materials, extension policy, assessment requirements, etc.), questions about the end of semester examination 12%, and other questions 8%.

The high degree of moderator input, and the evidence that the content of the forum was largely student-driven is indicative of the ‘content + support’ model. The majority of the interaction was question and answer (Q&A) between tutor and student, indicating that the discussion group was functioning primarily as a form on ‘online consultation’. Even though the moderator began in the initial stages of the semester to prompt student input by posting messages, this approach changed as the discussion group developed a life of its own and the moderator’s role became very much a *re*active one, rather than a *pro*active role. Because of the focus on tutor-student Q&A, the opportunity for student-student interaction was not emphasised, although there were a few occasions where students answered each other’s questions. This is one area where the use of the online discussion group in psychology may be extended. However, to take this path would change the nature of the way the discussion forum is being used currently. If the goal becomes to encourage student-student interaction in the sense of Salmon’s (2000) model toward developing knowledge construction and reflection, then a more structured, *issue-based* discussion forum may be appropriate. This move would raise issues related to flexibility, moderation, relationship to learning objectives and assessment, size of the group, etc.

Accessing the psychology discussion group

Those students who *did not* access the online discussion group were asked about their reasons for not doing so. Students could choose one or more reasons from a range of alternatives, as well as nominate their own reason. The majority of responses indicated ‘not thinking it would help me’ (N = 36) as the reason for not accessing the discussion group, and technological problems (e.g. access from home) (N = 25), or ‘didn’t have time’ (N = 25) were also fairly commonly cited. A few students nominated other reasons such as they obtained help from other sources or could not ‘be bothered’ (N = 16), and seven students indicated they did not know it was available. Students who *did* access the discussion group but did not post a message, were asked to nominate one or more reasons for not participating by selecting from a range of alternatives, or nominating their own reason. The most commonly cited reason for not posting a message was ‘did not have a specific question’ (N = 27). Some students also responded that they preferred to email (N = 12) or see a tutor (N = 10). Few students indicated technical problems (N = 5) or not being comfortable mailing to the group (N = 4) as the reason for not contributing.

Students were also asked whether they had previous experience with using online discussion groups, and if so, whether this experience was in another university subject. The results were clear: 43 (72%) of users of the psychology discussion group indicated prior experience, and 19 (44%) of these reporting experience in another university subject. Of those who did not access the discussion group only five students (6%) had used an online discussion group before, and in all cases this use had been for another university subject. Taken together, these observations suggest that better informing students about how the online forum may help them, and providing more direct (preferably 'hands-on') training on how to use the technology may increase the number of students accessing the discussion group. However, given the non-compulsory nature of the online 'consultation', even with increased awareness and training, there is likely to remain a proportion of students who do not need to access the discussion group. In sum, these findings highlight the need for a broad approach to the type of support available for students, if possible, to accommodate student preference.

Effectiveness of the psychology discussion group

Users of the discussion group were asked to evaluate the usefulness of the group (see Table 2). Overall, the range of responses suggests students were evaluating the usefulness of the discussion group positively. The most favourable evaluations reflect the most commonly discussed subjects identified in the content analysis (i.e. laboratory assignments and subject requirements), and also help in the subject generally. Although participation in the online discussion was not assessed directly, the emphasis on assessment-related activities suggests the discussion forum may be of indirect benefit to students in this regard. The opportunity to learn from other students' difficulties with the assignments may prompt students to think about issues and areas they may not have covered themselves, leading to improvements in the quality of their work.

Evaluation question	Mean	SD
Overall, the discussion group helped me as a student in this subject.	3.7	1.1
The discussion group provided clarification about subject requirements and access to course material.	3.7	0.9
The discussion group helped me with assignments.	3.8	1.2
The discussion group helped me overcome a sense of studying in 'isolation'.	3.4	1.1
The discussion group provided quick access to announcements from staff.	3.3	1.0

Table 2. Evaluation of the effectiveness of the online discussion group by users indicating the mean and standard deviation of responses on a 1(strongly disagree) to 5 (strongly agree) rating scale

Conclusions

Subject developers who are considering using online discussion groups need to ask three basic questions: who is interacting; for what purpose; and how can this interaction be facilitated and supported. Defining the answers to these questions in relation to the unique characteristics of a particular teaching and learning context will lead to quite varied uses of online discussion. In the context of this undergraduate psychology subject, the use of the online discussion group did serve a useful purpose in the form of tutor-student consultation. The face-to-face corollary of the use of this type of discussion group would typically be individual tutor-student consultation, usually offered during specific hours outside of class time (or by telephone or email for distance education students). In comparison, the online discussion forum offers support to a large group of students (with the learning benefits of exposure to other students' questions and feedback), and the flexibility of access to this consultation at a time and place of convenience to the student. As with any medium, however, individual student preferences and needs will vary, and this is not an argument for preferring online discussion to all other avenues of teacher-student interaction. The intended purpose of the online forum also impacts on the teachers' approach to moderating the discussion. The role of the moderator in this psychology subject was primarily to provide academic support to students in their work on laboratory assignments, and as administrative support to students in their management of the subject requirements. To be an effective moderator in this environment, the emphasis was on providing timely, useful and positive responses to student contributions. Finally, there were benefits for the teacher, as well as the students, in moderating the online discussion. For example, it was a useful way to gain an overview of student problems in the subject, particularly in relation to assignment-related content and skills. This feedback is valuable in future curriculum development.

Acknowledgements

Thank you to Tony Gilding from the Higher Education Development Unit at Monash University for helpful comments on earlier presentations of these findings.

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Curriculum design innovation in flexible science teaching

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Abstract: In this paper you will be introduced to a number of guidelines, which can be used to inform good teaching practice and rigorous curriculum design.

Guidelines relate to:
1. *application of a common sequence of events for how learners learn;*
2. *accommodating different learning styles;*
3. *adopting a purposeful approach to teaching and learning;*
4. *using assessment as a central driving force in the curriculum and as an organising structure leading to coherence of teaching and learning approach; and*
5. *the increasing emphasis that is being placed on the development of generic graduate competencies over and above discipline content knowledge.*

The guidelines are particularly significant in relation to adult learning and together they form the basis of a practical approach for learning module development. Three specific learning modules are used to illustrate the application of the guidelines. They are taken from a second year subject in introductory supercomputing that uses scientific case studies.

Introduction

Over the last three decades a number of papers have been published in the area of adult learning (andragogy) in higher degree institutions (Knowles, 1980, 1984, 1995; Perry, 1975, 1981; Westrup and Jack, 1998; Panasud and Lebaron, 1999; Pascual-Leone and Irwin, 1998; Schroth, Pankake and Gates, 1999; Healy, 2001). Andragogy has close links with pedagogy (children's learning), and some concepts in these fields are closely coupled (Healy, 2001). Through research it has been shown that adults learn best when they can see how what is being taught has relevance and applicability to their own lives (Knowles, 1980, 1984). For example, a science student that has a keen interest in aquarium fish can better appreciate scientific concepts and content related to pH, than a student who has a guinea pig as a pet.

Lecturers designing and developing educational materials to aid adult learning in the form of curriculum construction should consider a number of key factors related to the learners' background. For example:
- what the student does;
- where they do it;
- whether they like their work;
- what significant impact does that have on the student; and
- whether there is a sociological implication to it.

In any given semester we may observe different learners within the classroom. These different learners can be classified according to Perry (1975, 1981). The classifications take into account that the learners absorb information differently, depending (in part) on the relevance of the materials and the connection they can make with it. For this reason, we aim to develop educational materials that have high impact factors (for example, solving scientific problems that influence the ecological status and preservation of Australia). At the same time we try to incorporate these problems into their every day lives.

In addition to the key factors listed above, other associated issues have to be considered before adult learning can be effectively implemented in the classroom or in an online situation. For this reason it is essential to present material in forms that can be represented in ways that aid student and adult learning. In this paper, we analyse a unit offered in the Faculty of Science at the Queensland University of Technology, Australia. The unit *Introduction to Supercomputing* (one of four in the course) concerns supercomputing techniques, where the content and skills are developed through various assessment strategies and scientific case studies. The unit consists of three modules, where each module employs a different approach to adult learning.

In the *Introduction to Supercomputing* unit, the first module is based on background information, and is very factual. The second module is very much problem based: the students are engaged in solving real-life problems using introductory techniques. The third module focuses on application. It requires the student to solve certain aspects of specific real-life problems using efficient supercomputing approaches. Throughout the learning process, the learner's generic skills are enhanced by the use of strategic, thought-provoking and skill-development assessment items.

Building generic capabilities is a main focus of the curriculum structure behind adult learning. In Australia, TMP (formerly known as Morgan and Banks Employment Agency) claims that future jobs will harness the generic capabilities and skills of students in today's classrooms (MDU, 2001). These skills can be summarised as (1) the ability to work in a team, (2) commitment to life-long learning, (3) superior problem solving ability, (4) the ability to identify issues and (5) solving these issues intelligently. TMP has predicted also that 70% of children starting school this year will have job classifications after finishing tertiary education that we have not yet heard of, or which have yet to be categorised as employment opportunities. This statement by TMP enhances the need to produce graduates with generic capabilities and skills in the form of, for example, information literacy, creativity, critical thinking and the ability to engage in life-long learning.

Five guidelines for good curriculum design

Before we can develop any educational materials for teaching purposes, we must understand how learners learn, and how they acquire knowledge and skills. In this paper we offer a set of five guidelines that together form the basis of a practical approach for the development of well designed learning modules.

The first guideline concerns the application of a common sequence of events for how learners learn. In brief, the sequence should move from acquisition to assimilation to application. That is, learners acquire knowledge before they fully understand it. Then the learner can move on to application, which demonstrates their ability to apply their understanding to specific applications (see for example Kolb, 1976, 1981; Ramsden, 1988; Merriam and Caffarella, 1991; Laurillard, 1993; Marton and Booth, 1997). Consequently, we have the first guideline for good curriculum design, in which learners' first acquire 'facts'. As facts are acquired, they are transformed and assimilated into the learners' existing/developing cognitive structures (i.e. they learn to understand the facts). As a result, the acquisition of information should ideally relate to what learners already know (i.e. past experiences) and should be presented accordingly[1].

Once a body of knowledge or collection of facts is understood, learners can learn how to apply that understanding.

Accommodation of different learning styles is the second guideline in good curriculum design. As good practice, the educator or teacher should accommodate and adopt different learning styles in the classroom and online (Smith and Kolb, 1986; Manner, 2001; Smith, 2001). These learning styles

[1] The authors are aware that learning is mediated through the making of meaning and would like to make clear that acquisition is therefore a process which occurs *hand in hand* with a learner's developing understanding. The main point here is that a learner needs to understand some thing which exists within a disciplinary context. A secondary point is that initial understanding may be limited, particularly if a learner initially adopts a surface approach to learning.

include: (a) aural, where learners prefer to learn by listening; (b) kinaesthetic, where learners prefer to learn by doing; and (c) visual, where learners prefer to learn by use of illustrations, visualisations and graphical representations.

The third guideline in good curriculum design has to do with stimulating the learner to evoke interest in the content material being taught. This is underpinned by a purposeful approach to teaching and learning. In the literature there is a common distinction between surface and deep learners (Säljö, 1975; Entwistle, 1984; Chickering and Gamson, 1987; Entwistle and Tait, 1990; Ramsden, 1992, 1993; Tang, 1994; Kember, 1998). The literature also refers to 'strategic' learners (Richardson, 1994). Surface learners seek to obtain knowledge through memorisation, and accordingly, their preference is to be told the 'facts' related to a certain topic of study. Surface learners do not seek to understand, rather they memorise and regurgitate these 'facts'. Conversely, deep learners seek to learn through understanding. They are more likely to find the content intrinsically stimulating and interesting, and are more likely to want to be made to think for themselves. Finally, strategic learners will (in principal) do anything within their ability to either (a) obtain marks, or (b) get whatever else it is they want from the learning experience (e.g. real-life applications). They will interpret the demands of the current learning situation, weigh that against their strategic objectives and desired outcomes, and then decide on an appropriate learning strategy. In summary, it is important to express a clear purpose when teaching as this will assist the learners' learning. The best kind of learning outcome will be achieved when the learners share that purpose. Ideally, the learners and educator will have a common learning objective. Motivation of the students is subsequently an issue, and can be maintained by making the student perform certain tasks through assessable items.

To motivate adult learners, weighted assessment that contributes to a final mark should be used in such a way that emphasis is placed on the most significant learning outcomes. For this reason, the fourth key guideline is the use of assessment as a central driving force in curriculum design and implementation (see for example Biggs, 1987, 1999; Boulton-Lewis, 1998; Brown and Knight, 1994; HERDSA, 2000). Assessment is also used to organise the learning material leading to coherence in the teaching and learning approach. It is arguable that assessment is the only activity that students have to complete, since it is the only way they can accumulate marks. All other activities may or may not lead to gaining more marks. Students will perform and engage in activities that they know will result in the obtainment of marks, or assist with the achievement of their own strategic objectives and/or initiatives. Good curriculum design aligns the assessment and the associated activities needed to complete that assessment, to capture the learning that the educator sets out to achieve. This will lead to an obligation for the learners to behave in ways that lead to the desired learning outcomes. If we choose to accept such an argument, then the types of assessment used, the timing of assessment items and the integration between items are all of vital importance.

There is an increasing emphasis being placed on the development of generic graduate competencies and skills over and above discipline content knowledge (Leonard, 2000; Pearsall, Skipper and Mintes, 1997; Down and Stewart, 2001). TMP in Australia has identified a number of key competencies required of graduates (MDU, 2001), some of which include (a) teamwork, (b) problem solving, (c) critical thinking, (d) information literacy, and (e) life-long learning. Such skills are increasingly important – perhaps essential – given that a person is currently expected to hold approximately seven different full-time jobs within their working careers. The incorporation of the development of generic capabilities is therefore crucial to good curriculum design, and is regarded as the fifth fundamental guideline.

In summary, the days in which tertiary institutions can run courses that produce graduates with a simple understanding of a particular body of knowledge are gone. What is needed now are courses which produce graduates who are able to make good use of their understanding, and to be able to do this within the socio-political context of the workplace.

Three illustrations of the five guidelines for good curriculum design

In this section three modules from a second year *Introduction to Supercomputing* unit of a Bachelor of Applied Science undergraduate degree at the Queensland University of Technology are discussed. The three modules together form the core content material for this unit. Each module has associated with it assessment items that assess content material and develop certain generic skills.

The first module is called ‘Supercomputing: Background, Trends and Concepts’. Figure 1a illustrates the concept map (outline of content and assessment) for the first module. Similarly, Figures 1b and 1c illustrate the concept maps for modules 2 and 3, ‘Introduction to Scientific Computation in Matlab’ and ‘Introduction to Parallel Processing in Scientific Computation’, respectively.

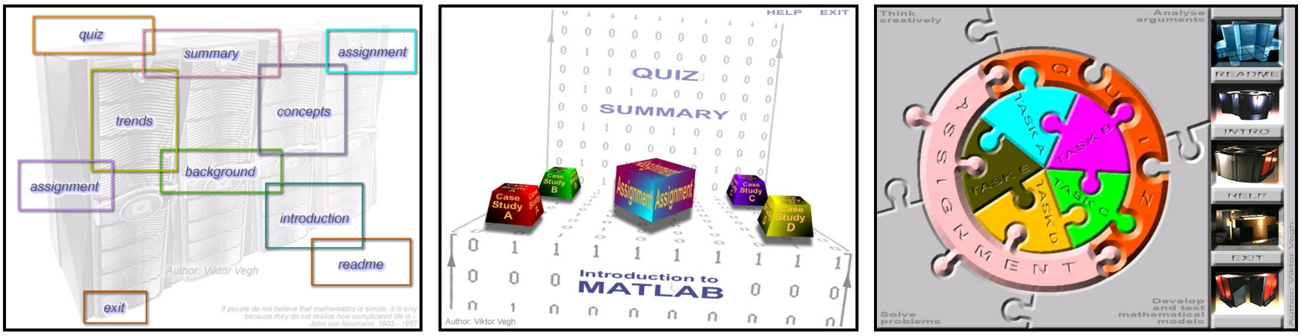

Figure 1. The concept maps for the three modules (a) Supercomputing Background, Trends and Concepts, (b) Introduction to Scientific Computation in Matlab, and (c) Introduction to Parallel Processing in Scientific Computation

This section identifies how each module relates back to the five guidelines of good curriculum design and how they collectively integrate the content of the entire unit. First, each module is outlined separately, after which the global effect is studied.

In Table 1 the five guidelines of good curriculum design are highlighted and are examined in relation to the modules. To some extent, each module relates to all five guidelines, however, each differs in emphasis. Module 1 consists primarily of introductory content material, which is presented in an interesting but primarily factual manner. The different backgrounds of the students within the unit are acknowledged, and hence the learning process within the modules aims to accommodate the different learning styles expected from the students. A purposeful approach is adopted by relating the background, trends and concepts to real-life scenarios. These real-life scenarios are presented within the context of the course. Therefore, the students can relate, and make a connection with, the content material studied. The assessment tasks act as a glue to hold the different pieces together and also builds student generic skills in the form of information literacy and research.

Module 2 shown in Figure 1b focuses on the delivery of the content material through real-life case studies from scientific applications. The case studies are carefully chosen from various disciplines within science, and in some cases are related to problems that can have an effect on the students’ lives. The purpose of this module is clearly stated throughout the learning process by linking the concepts of supercomputing solution strategies to the case studies. The five case studies are diverse, and each is presented in a different way to help aid the various learning styles of the students. Assessment of this module is done via an assignment and a quiz. The assignment enhances student ability in problem solving, critical thinking and teamwork (see Table 1). The quiz is aimed at testing the technical knowledge gained and obtained in the course of study.

Curriculum Design Guideline	Module 1	Module 2	Module 3
Application of a common sequence of events	Concepts in this module have an introductory nature, material is mostly factual	Case studies are explained in detail to build understanding	Takes simple to complex ideas from the case studies and develops problem solving skills for certain aspects, thus this module focuses on application
Accommodating different learning styles	A student may elect to take a different path in studying this module (for example student A may go to trends before concepts, and student B may choose the opposite)	All case studies are different, and they do not necessarily need to be completed in any given order	A number of different solution strategies are demonstrated via the delivery of the materials
Adopting a purposeful approach to teaching and learning	Real-life scenarios are used to gain their appreciation of the need for such tools	Case studies identify the need for supercomputing tools, techniques and skills	Purpose is linked back to the case studies and the introductory background content
Using assessment as a central driving force in the curriculum design	Students have to cover the main areas of this module to obtain marks (i.e. trends, concepts and summary)	The main elements of the case studies are captured in the assignment in relation to the appreciation of supercomputing, the quiz tests technical knowledge	Assessment incorporates their previous knowledge, requiring them to evaluate and identify with certain problems critically
Development of generic graduate competencies	Assessment is constructed in a way that builds information literacy and research skills in the learners	Problem solving skills and teamwork are developed in this module	The learners are required to reflect on the problem studied, and identify how to better the solution strategies, problem solving and critical thinking skills are developed here

Table 1. The relation of the modules to the five guidelines of good curriculum design

Figure 1c illustrates the last module in the *Introduction to Supercomputing* unit. This module collectively brings together the concepts learnt so far. Students are required to apply their background knowledge, understanding and appreciation of the need for supercomputing. The third module consists of tasks that the students have to complete, i.e. it focuses on application of understanding. These tasks have been identified as critical problems that need to be solved within the different case studies. Table 1 highlights the five curriculum design guidelines achieved in this module for adult learning.

When considering the student outcomes for the whole unit, the first guideline (acquisition to assimilation to application) is addressed clearly. In the context of the unit, module 1 aims to build knowledge for the student, whilst module 2 tries to make the student understand why it is that we need this knowledge. The last module requires the students to apply their acquired knowledge to certain aspects of the different case studies and problems that they have studied in this unit. The final grading for each student includes three quizzes, one for each module. The quizzes accumulate approximately 30% of the final mark. Every quiz is weighted differently, depending on which step of the learning process the quiz is examining. When finalizing the marks, most emphasis is placed on application, followed by assimilation. Each module also has associated with it an assignment that is weighted in the same way as the quizzes. Accordingly, a large portion of the student's mark is made up from module 3, which is the most important in terms of the unit's learning outcomes.

Conclusion

In this paper we have identified five critical curriculum design guidelines and shown how these can be applied through illustrations from a science unit. These guidelines are based upon fundamental educational theories that are readily available in the literature. We argue that together the design guidelines discussed in this paper encapsulate, inform and characterise good teaching practice and together they form a basis of a practical approach for the development of well designed learning modules, not just in science, but in a wider context.

We have argued that the student's understanding of the content material being taught must be prefaced by the acquisition of the underlying factual knowledge. Hence, the first step is the provision of factual content. Only after the student has acquired factual content and developed an understanding of the material being presented, are they able to apply it to a particular problem. This is the basis of the first guideline – the application of a sequence of events for how learners learn.

It is well known that students display a range of different learning styles. The focus of the second guideline is to address this issue by the incorporation of interactive, visual and auditory learning materials. In addition, this should be supported by a teaching approach that exhibits a common purpose between the teacher and student. This helps to stimulate and enthuse the student, which can lead to improved teaching and learning outcomes. The third guideline is based on this approach.

Students are necessarily driven by assessment. Thus, the strategic use of assessment items with respect to content and placement will collectively guide student learning and the resulting knowledge and understanding. The use of assessment as a driving and organising device is therefore recommended, and leads to the fourth guideline. The fifth and final guideline recognises the increasing emphasis that is being placed on the development of generic skills. Examples of how this guideline can be incorporated into learning modules, and indeed all other guidelines, are illustrated in the science unit discussed in this paper.

In conclusion, this paper has drawn together a number of important educational issues that have been structured into five guidelines. The authors believe that these form the basis of a practical approach for the development of well designed learning modules.

Acknowledgements

The authors would like to thank Australian Partnership for Advanced Computing (http://www.apac.edu.au/) for funding the Queensland University of Technology through Queensland Parallel Supercomputing Foundation (http://www.qpsf.edu.au/) to develop educational materials in the field of Advanced Scientific Computation. We also appreciate the support from SGI® and Intel®. Our thanks also to Dr Noel Meyers, School of Natural Resource Sciences, Queensland University of Technology for his engaging discussions and support.

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Introductory astronomy: setting goals and measuring achievements

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Introduction

In 1998 a one semester (6 credit point) introductory astronomy unit, PHYS1500 *Astronomy*, was introduced by the School of Physics to fill a long-perceived student demand for astronomy. Students from all across the University enter *Astronomy,* bringing highly variable physics and mathematics backgrounds. Consequently, a largely non-mathematical and 'concept-based' approach was adopted, in clear contrast to the more mathematical and problem-based approach typical of physics courses. Nonetheless, astronomy and astronomical data *is* intrinsically numerical and the students face this in various places, notably the computer-based laboratories.

This unit of study covers a full range of astronomical topics in one semester, with six contact hours per week as is typical of a 6 credit point Science unit. However the material is presented in a variety of ways that distinguish *Astronomy* from typical physics units:

- a comprehensive, largely non-mathematical textbook;
- fewer lectures than for a typical physics unit;
- 'seminars', featuring invited lecturers and topics building on the core syllabus;
- tutorials based around small group discussions led by teams of students;
- laboratory exercises presenting realistic data based on computer simulation of observations;
- hands-on telescope observations, both daytime and night-time; and
- an essay, but no other formal assignments.

Further details can be found on the Web at http://www.physics.usyd.edu.au/ugrad/astro.html.

The broad goals of the unit are:

- to present astronomy in a way accessible to students from diverse backgrounds;
- to improve the students' conceptual and factual knowledge of astronomy;
- to convey some insight into how science is done, what part it plays in society; and
- to develop some of the communication and computer skills required in a graduate.

Astronomy has been very successful, growing to over 200 students in 2000 and 2001. Their response to the unit has been excellent and at least one quarter of them have suggested that they would consider doing a second astronomy unit if it were offered. Popularity and enrolment numbers are one measure of success but, with its diverse background of the students, is *Astronomy* achieving its goals? To address this question we have studied the student population enrolled in the unit and used a variety of survey tools to probe student attitudes and understanding, including a southern hemisphere version of the Astronomy Diagnostic Test (ADT).

Analysis of student performance

Student academic background

Approximately 120 students completed the unit in 1998 and 1999, rising to 174 in 2000 and 197 in 2001. The profile of the student body remained similar throughout, with 60-70% of students in their first year of university, approximately 15% were in their second year, and approximately 10% in their third year. Approximately 40% of students are female. The proportion of *Astronomy* students who are enrolled in the Science faculty is typically just under 70%, with a further 10-20% from the

Faculty of Arts. The remainder come from a range of other degree programs, with Engineering rising over 10% in 2000 as aerospace engineers entered the class.

Results versus student qualifications

The final mark is one clear measure of the performance of the students in *Astronomy*. Comparing these results with the background of the students provides an indication of our success in meeting the aim of providing a course suitable for students from across the university. Data from the 1999 class are used in this analysis and it is representative of results from all four years.

The results for the class (students who complete the course by sitting the final examination) show a broad distribution in final scaled marks with a mean mark of 61% and a standard deviation of 15%.

The physics background of the students can be gauged from the physics taken at school or in their university career to date. Looking at the first year students only in the 1999 class, only 40% took physics in their final year of high school (i.e. did physics in the NSW Higher School Certificate (HSC) examination, or equivalent). Their *Astronomy* results show a median mark of 64% (Figure 1(a)), compared to 59% (Figure 1(b)) for their contemporaries with no physics background from their final year of high school. The latter group also showed more students with poor marks, however the differences in the distributions are not significant.

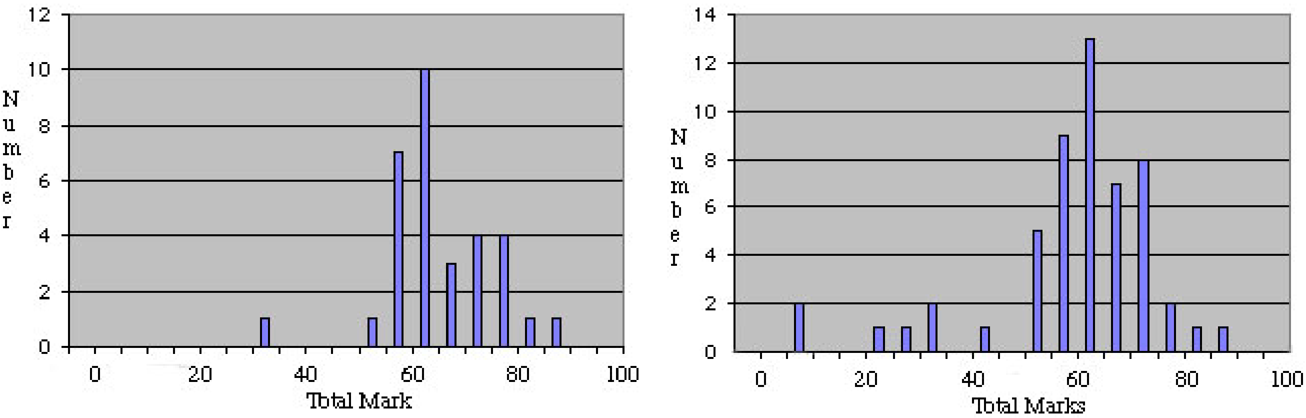


Figure 1. Distribution of total marks for 1999 students (a) with and (b)without physics in their final year of high school

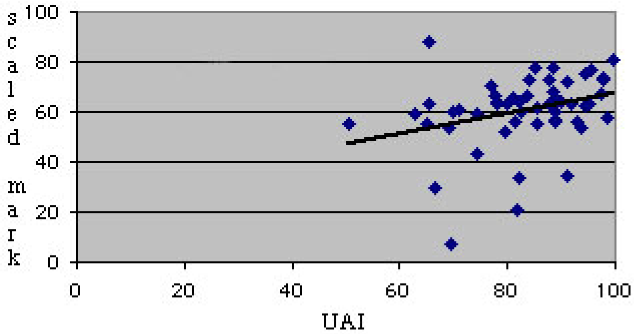
Half of the students had experience in physics at university, 46% in first year physics courses only (including a small number at the advanced level), and another 5% at second year level. There was no significant difference in results of students with and without a university physics background. The distributions were very similar, with median marks of 64% and 63% respectively.

A comparison was also made of results for students in their first year of university and those in their second and higher years, irrespective of their physics background. For these there is again a slight difference between the median of 61 for first year students and 64 for higher year students. One might expect that students with more experience at university do a little better, but the significance is marginal.

Finally, considering only students in their first year of university, the *Astronomy* examination results were compared with measures of student performance across a broad range of subjects. The first of these is the Universities Admission Index (UAI), derived from marks at the HSC examination. The result (Figure 2(a)) is almost no correlation (r^2~0.09) between UAI and *Astronomy* mark.

The second broad measure is the Weighted Average Mark (WAM) of the students' final results from all their university courses. The analysis was restricted to first year Science students to minimise other variables in the comparison. The result (Figure 2(b)) is a stronger correlation

(r^2~0.43) as expected, since overall university performance is likely to be a good predictor of performance in *Astronomy*.



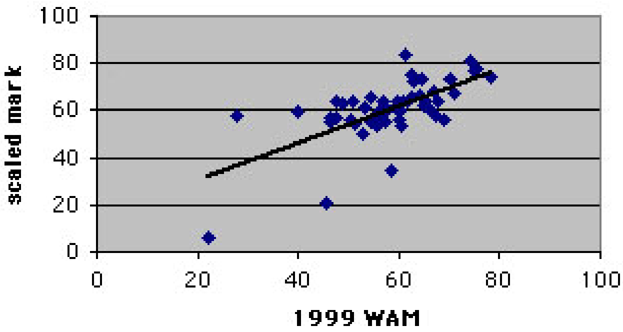


Figure 2. (a) For all 1999 students, correlation of *Astronomy* examination mark versus Universities Admission Index (UAI), (b) For 1999 Science students only, correlation of *Astronomy* examination mark versus university Weighted Average Mark (WAM)

The conclusion to be drawn from these data is that good academic performance in *Astronomy* does not depend significantly on student background. Furthermore, when looking at the students who topped the rankings, they represent a cross-section of the class in every respect. Given the range of student backgrounds, these results are remarkable and indicate that the unit achieves its aim of being accessible to all.

Combatting misconceptions

The final examination is one measure of student knowledge, but educational research judging the usefulness of introductory physics and astronomy courses often emphasizes their effectiveness in combatting basic misconceptions that students bring to the course from their experience of the world. This is often judged by a 'Misconception Quiz' administered at both the start and the end of the course, featuring questions designed to probe students' understanding of basic concepts. There are several reported studies of performance in astronomy misconception quizzes by university students (for example Bisard et al., 1994; Trumper, 2000, 2001; Zeilik, Schau and Mattern, 1998; Zeilik and Bisard, 2000), and even more by secondary and primary (elementary) school students (for example Dunlop, 2000).

The quiz employed in *Astronomy* in 1998 and 1999 (see http://www.physics.usyd.edu.au/ugrad/astro/astro_quiz1.html) was adapted from one supplied by Margaret Mazzolini and used at La Trobe University and Swinburne University of Technology. It asked many typical questions about positional astronomy using True/False statements, and was extended to include the full range of stellar, galactic and extra-galactic astronomy covered in the lectures. It was intended to explore the range of knowledge students brought to the course, and gauge how much the course influenced that body of knowledge. It concentrated on 'factual' questions, rather than more deeply imbedded 'structural' concepts that students have developed from their experience of the world. Factual misconceptions are expected to be easier to change.

The quiz was given twice each year – once at the start of the semester and once near the end. In both years the percentage of correct responses at the first attempt averaged approximately 70%, increasing by 7 to 8% at the end of the semester (see Figure 3). Looking more closely, it is clear that more questions were answered poorly in the second half of the quiz, when the emphasis shifted from basic astronomical concepts and planetary ideas to astronomy beyond the solar system. The earlier questions on basic astronomical concepts were answered with 60-80% correct responses, where overseas quizzes often report scores approximately 40-60% correct on such questions. These success rates may reflect the rather different student backgrounds around the world, but are impossible to compare objectively because of the lack of standard questions. The lower scores reported in

Trumper's Israeli study (2000) for example, may reflect the fact that slightly fewer of his students were enrolled in Science and almost none had any high school background in physics.

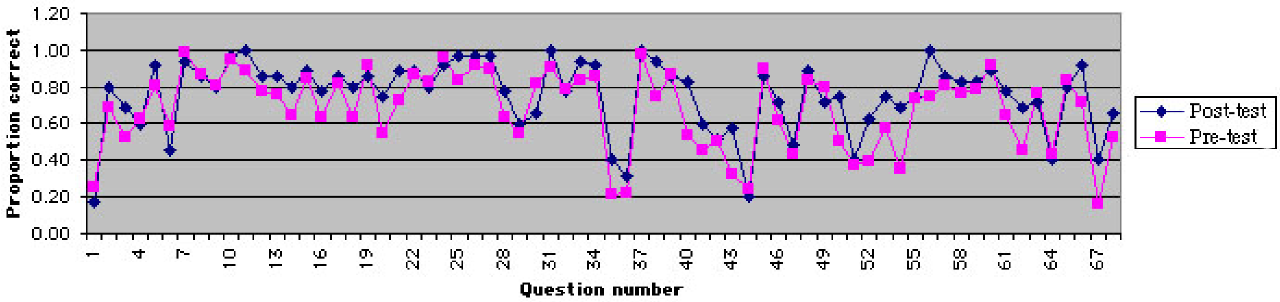


Figure 3. Percentage of correct responses to questions on the 1999 Misconceptions quiz. Pre-test results are typically slightly lower than the post-test results.

The quiz responses deserve closer study using student interviews, but the questions also need to be validated more carefully. The inability to compare these results with others is best addressed by adopting a standard set of questions.

In physics, a standard undergraduate test, the Force Concept Inventory (Redish and Steinberg, 1999), has proven to be a useful tool. In astronomy, the multiple choice Astronomy Diagnostics Test (ADT) has recently been developed and validated as a standard test for undergraduate non-science majors taking an introductory astronomy course (Hufnagel et al., 2000). Version 2.0 of the ADT (see http://solar.physics.montana.edu/aae/adt/) was adapted very slightly for the southern hemisphere and used in *Astronomy* in 2000 and 2001 in place of the earlier Misconception Quiz. ADT questions are intended to test concepts rather than the more factual content tested by the earlier quiz. Questions range from basic astronomy (What is the phase of the Moon when it appears to completely cover the Sun?) through physical concepts (Why do astronauts inside the Space Shuttle float around as it orbits the Earth?) to a little astrophysics (What colour are the hottest stars?). More information on the southern hemisphere ADT can be found at http://www.physics.usyd.edu.au/super/ADT.html.

Analysis of responses by the 2000 class to the southern hemisphere edition of the ADT indicate correct response rates of 45% beforehand, rising to 53% at the end of the semester (see Figure 4). In both cases however the spread is wide with standard deviations of 20%. Looking at individuals, the average improvement from pre-test to post-test is 11%, again with a wide spread.

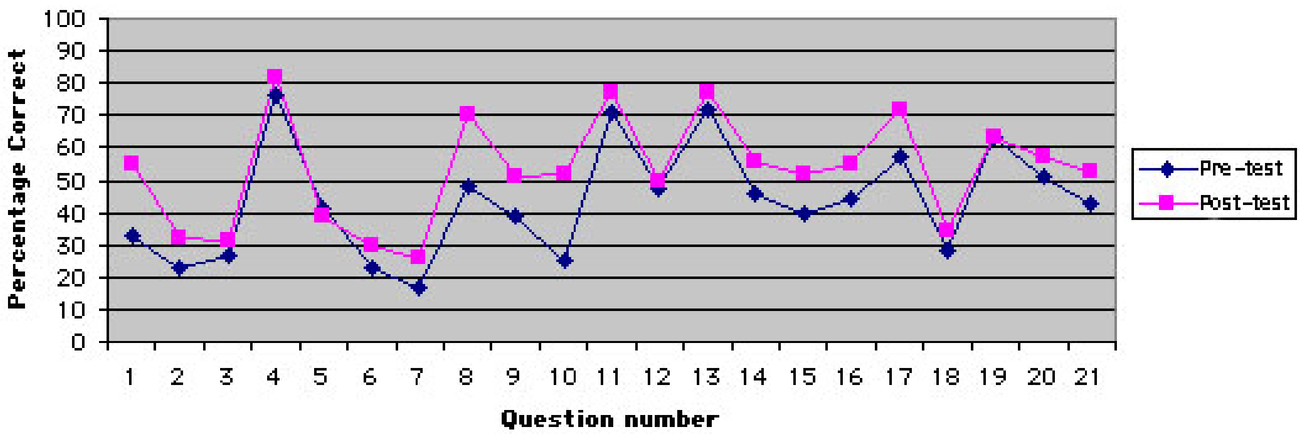


Figure 4. Percentage of correct responses to questions on the 2000 Southern Hemisphere Edition of the ADT. Pre-test results are slightly lower than the post-test results.

These results should not be closely compared with ADT results in the US (Hufnagel et al., 2000) since the southern hemisphere version has not been formally validated with our student group. However the *Astronomy* results do show a somewhat higher rate of correct answers than most of the US universities and colleges surveyed (typical pre-test rates of approximately 35% or less), consistent with the result from the earlier Misconception Quiz. It is likely that this mainly serves to emphasise the different body of students being tested and is therefore a warning against carrying US conclusions about introductory astronomy into the Australian context. Initial results suggest that New South Wales students come to university with a relatively high level of astronomical knowledge, even before changes to the high school syllabus. *Astronomy* further improves the average student response, as revealed by both types of quiz.

Validation of the southern hemisphere edition of the ADT requires participation by a wide group of Australian universities and careful study of the responses in the Australian context. This has begun in 2002 with 4 lecturers at other universities agreeing to administer the southern hemisphere edition of the ADT in semester 1, and potentially more in semester 2.

Student response

We have not interviewed students to probe their opinions on the course, but we have used a variety of questionnaires to probe their subjective attitudes.

Course modules in physics are the subject of routine exit questionnaires to gauge student reaction. The standard format allows direct comparison of student response to different parts of their course and different lecturers. The overall rating for *Astronomy* each year averages around 4.0 on a 5 point scale which is an excellent result, especially for a large and diverse class group such as this. Typical results for junior (first year) Physics units average around 3.3.

The most revealing aspects of any questionnaire are the free-form student responses, although their self-selected nature means that they cannot be treated as strictly representative. Nevertheless they consistently indicate that the unit is well regarded and certain components such as the laboratories, web-based review questions and the night-time viewing sessions are especially popular.

During the 1998 course the Sydney University Physics Education Research (SUPER) group also surveyed various student expectations of the course beforehand, and later repeated the survey to judge how well these expectations had been met. Not surprisingly, 80% of students suggested initially that they expected to gain a general knowledge of astronomy and an understanding of the universe and how it works. This expectation was met for a majority of students.

More specific questions were also asked, such as whether they expected the course would give them a deeper understanding of their own place in the universe. The expectation was high (median value of 4.1 on a 5 point scale) and, as for most questions, these initial expectations were exceeded in the post-course survey. The responses to the entire survey were generally very positive.

All these data indicate a high level of student satisfaction that the style and content are appropriate to their expectations. The question still remains as to whether individual components of the unit presentation are effective. Subjective student opinion is provided in the 1998 survey and some questions on the routine exit questionnaires. The only component to rate poorly is the web-based Discussion Forum which has not yet succeeded in generating genuine discussion among the students, although it has found a place in allowing each tutorial class to report their conclusions to the whole student group.

Conclusion

PHYS1500 *Astronomy* at The University of Sydney is, in many ways, typical of introductory astronomy units in Australia and overseas, although more challenging than many. Are the style and level of presentation of the introductory astronomy units like this appropriate?

An analysis of student examination results clearly indicates that student background is not an impediment to success in *Astronomy*. The highest achieving students represent a genuine cross-section of the student body. Furthermore, surveys indicate that the unit successfully meets student expectations and is popular. Available data do not allow a clear judgement on the educational effectiveness of each component of the unit, but it is apparent that no component is failing in any significant way. On the other hand, the improvement in quiz responses between pre- and post-tests is relatively small, consistent with experience in traditional lecture courses.

These results serve as a baseline for the study of students entering in 2002 and beyond, who are products of a new HSC Physics syllabus in NSW where astronomy features much more prominently. To date however, only around half of the *Astronomy* students have done physics in their last years of school, so this change may increase the difference in student background and pose a greater challenge to the course.

Further work with the southern hemisphere edition of the Astronomy Diagnostic Test (ADT) is clearly justified to measure performance in Australian circumstances and look for changes in student performance as a result of changes to the HSC.

Acknowledgments

The author would like to acknowledge the involvement of other members of the School of Physics in designing and delivering the Junior Astronomy unit, in particular the following staff – Tim Bedding, Anne Green, Richard Hunstead and Mark Wardle – and various postgraduate students. The preparation and analysis of the 1998 class surveys was managed by Ian Sefton for the Sydney University Physics Education Research (SUPER) group.

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Evaluation of a research based teaching development in first year physics

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Abstract: The School of Physics at The University of Sydney has developed workshop tutorials for first year physics in accord with findings in physics education research. The students work in cooperative groups at a variety of tasks including hands-on activities and discussion questions. The tutorials are self-paced and focus on understanding, with tutors acting as facilitators. A CUTSD funded project to develop a workshop manual is now nearing completion, and the workshops are already being used at other Australian universities.

Formative evaluation, such as the use of minute papers and a feedback box, has helped to improve the workshops. The students provide a 'snap-shot' of a particular workshop by filling in a minute paper, which allows that workshop to be revised and improved. Summative evaluation of the workshops has been provided by Likert scale surveys and focus groups. The surveys have been administered to large numbers of students and provide a broad overview of the workshops. The focus groups, run by the Institute of Teaching and Learning at The University of Sydney, provide in-depth information from a small number of students. The information from the focus groups and the surveys has enabled the expansion of the project both within and beyond The University of Sydney.

The teaching development – Workshop Tutorials

Workshop Tutorials have been developed at The University of Sydney in response to changing student needs and expectations and poor attendance at traditional tutorials. The workshops were developed over several years by Manjula Sharma and colleagues in the School of Physics and are based on findings from physics education research, and ongoing informal evaluation of the workshops.

The workshops are a student centred learning environment, rather than a traditional teacher centred problem solving tutorial. The students sit in cooperative groups of three or four students, each group at their own table. The students are encouraged to work collaboratively on each problem, discussing each question and arriving at a plan of attack before beginning. This is an important aspect of the cooperative grouping – often when students are put into groups for problem solving activities they work as individuals, only comparing solutions at the end. When this happens the students are missing out on an opportunity for developing communication and teamwork skills. Tutors in the workshop tutorials encourage students to solve problems as a group, rather than as individuals, and try to interact with an entire group, rather than a single student when questions arise. Group problem solving has been shown to be of value not only to the weaker students in a group, but also to the stronger students. Weaker students benefit from peer tutoring while stronger students benefit from being forced to articulate their knowledge, often clarifying it in the process (Heller et al., 1992). In general, students involved in interactive learning schemes consistently out-perform those in the more traditional teacher oriented systems (Heller, Keith and Anderson, 1992; Hake, 1998; Thornton and Sokoloff, 1998). Students working in groups also tend towards 'deep learning' more than students working alone (Ramsden, 1992). This is because by discussing problems, particularly conceptual or qualitative problems, they are forced to discuss their own assumptions and question their understanding of the subject. Students explaining their own understanding to another student are likely to try to make links to their previous knowledge, making analogies to help explain a new concept in terms of familiar ideas. This helps them to relate the new knowledge or understanding to their existing knowledge and experience, giving them a more coherent, and less fractured, understanding of the topic. The tasks, in particular the qualitative questions described below, are particularly designed to encourage students to draw on their experience and previous knowledge, as well as knowledge from other subjects and courses, to help them construct a ‘big picture’ and coherent understanding of the physics they are learning. The use of context rich questions which relate to other studies, such as engineering or biology, help to do this by making them link ideas in physics to what they are learning in other classes.

First year students often experience difficulties in making the transition from high school to university. They move from an environment where they sit in small classes and they know the other members of the class and the teacher. When they come to university they are often in large classes where they know no-one, and, according to a 1995 report by McInnis and James, well over a quarter worked in isolation from their peers and were not interested in extra-curricular activities. Working in a small group in the workshop tutorials means that from almost the very beginning, they know at least two or three other people in the same class, and can discuss problems in physics with those people. This can be very reassuring to students who otherwise find the transition difficult.

The students are presented with three types of problem to work on in each tutorial; conceptual/qualitative problems, hands-on activities requiring an observation and explanation and quantitative questions requiring calculation.

The qualitative questions aim to address student’s conceptual understanding of physics and encourage discussion within the group. These questions explore concepts which students find difficult. Some of the questions are based on misconceptions identified in physics education research, for example student conceptions of simultaneity in relativity (Scherr, Shaffer and Vokos, 2001) and difficulties with Newton’s laws (Hestenes, Wells and Swackhamer, 1992). Some questions have also been based on student misconceptions which have appeared on previous examinations, for example ‘x-rays have momentum, therefore x-rays have mass and are particles’. The questions are particularly designed to challenge students existing ideas, and encourage discussion within the groups. Tutors are encouraged to use Socratic dialogue when discussing these questions with students, drawing out their ideas rather than simply telling them the answer.

The hands-on activities have been carefully chosen to illustrate particular concepts of physics, and encourage students to discuss the concepts while answering questions from the worksheet. The activities are usually simple in nature and may have been seen by students as lecture demonstrations. The workshop tutorials give students an opportunity to explore the activities in their own time and on their own terms. Students at a concrete operational stage of development need to see physical phenomena directly while they manipulate the equipment themselves so that they can progress on to the abstract operational stage, which characterizes experts in the subject (Laurillard, 1992). Even students who are comfortable with dealing with abstract ideas enjoy the opportunity to see applications and real-life examples of the physics they are learning. The personal interaction with the apparatus rather than passive observation is important in learning. In addition, many of the activities involve simple apparatus such as detergent, kitchen scales, smoke detectors and other household items, allowing students to revisit the activities at home in their own time, and explain the activity to family or friends thus further reinforcing their understanding. Using familiar objects, which students may not have considered from a ‘physics viewpoint’ helps them to link their previous knowledge of how things work to what they are learning in physics, and encourages them to consider physics around them and at home, not just in the laboratory and tutorial room. This helps them to compartmentalize their knowledge less, and form a more coherent view of the world.

The quantitative questions are generally context rich, with a context appropriate to the course, for example there are questions on blood flow through the circulatory system in the fluids workshops for the biological and environmental physics students, and fuel flow through injection systems for engineering and applied physics students. This helps give relevance to the physics, particularly for non-physics majors. As described above, helping them to relate the theoretical knowledge learned in lectures in everyday experience and knowledge of other subjects.

Evaluation

Evaluation plays an important role in any teaching development. Even prior to introducing a teaching development, evaluation of existing teaching and learning may identify problems or needs which are not being addressed, showing the need for a new initiative. Obviously it is important to know what the problems are before implementing new teaching strategies to address the problems. This gives a basis for comparison, so that the level of success of the new teaching development can be assessed.

When a teaching development is first introduced it is important to have formative evaluation of the development, to allow it to evolve. This is true whether it is an original innovation, or an 'imported' innovation being used in a new setting.

Formative assessment is often very informal, for example anecdotal reports of teaching staff and students' comments. This is very important in the initial design and testing phase of a teaching development. Formal evaluations, such as minute papers and student-staff meetings, help with the testing and evolution of a teaching development.

One weakness of informal evaluation, such as anecdotal evidence, is that a few complaints about a particular aspect of a development can have a very large effect on the development – the squeaky wheel getting the oil. For example, there are always a few vocal students who do not like group work, and are very clear about it. This can give the impression that cooperative grouping is not popular with students. However surveys to large numbers of students reveals that most students (the silent majority) in fact enjoy that aspect of the workshop tutorials. Hence it may be important to have some formal, formative evaluation of a new development, rather than relying on a small amount of informal feedback.

Summative evaluation, such as large scale surveys of students and focus groups, may be important for extending the teaching development. For example, results of early evaluation of the Workshop Tutorials led to a CUTSD grant to fund 'The Workshop Tutorial Project' (Wilson, Sharma and Millar, 2001). The grant enabled the further evaluation and development of the workshop tutorials, enabling the spread of the workshops beyond The University of Sydney. For a description of the early evaluation process leading up to the grant application see Sharma et al. (2001). A summary of the different forms of evaluation used is shown in Table 1 below.

	USyd regular, advanced, fundamentals technological	USyd CCHS bridging course	UNSW optometry	UWS engineering	ACU environment al science	USyd primary education
minute papers		yes, n = 110	yes, n = 43	yes, n = 33	yes, n = 18	yes, n = 127
surveys	yes, n = 415				yes, n = 21	yes, n = 108
focus groups	yes, n = 29					yes, n = 3

Table 1. Summary of forms of evaluation used for the Workshop Tutorials. USyd – The University of Sydney, CCHS – Cumberland Campus Health Sciences, UNSW – The University of New South Wales, UWS – University of Western Sydney, ACU – Australian Catholic University. n indicates the number of students contributing to each evaluation.

Formative evaluation of the Workshop Tutorials

Four main methods of formative evaluation of the Workshop Tutorials have been used – these are a feedback box for tutors and students in the tutorial room, tutor meetings reviewing the tutorials, minute papers and focus groups.

The feedback box and tutor meetings provided informal feedback, allowing immediate action to be taken on minor problems, for example errors in worksheets or broken equipment.

Minute papers and focus groups provided more formal feedback. Minute papers are short surveys consisting of three open questions, plus space for comments. These literally take only a minute to fill in, and are not a major imposition on students who may already be over-surveyed. The questions typically used on the minute papers were:

- What helped you to learn in this tutorial?
- What hindered you from learning? and
- What is one thing which is still unclear?

The minute papers were used with engineering students at University of Western Sydney, environmental science students at the Australian Catholic University, optometry students at The University of New South Wales and an array of different students at The University of Sydney, see Table 1 for details.

For all groups but one (optometry at UNSW), the most common answers to 'What helped you to learn in this tutorial?' were the activities and the group work. This indicates that students find working in a small group a valuable learning experience, a result reinforced by comments in the focus groups, described later. Many students also made comments on the hands-on activities, not only stating that they enjoyed them, but that they helped them to learn. One student responded to the question 'What helped you to learn in this tutorial?' with '*being able to do things myself, instead of just watching the lecturer do it*'. The figure below summarises the answers to the question 'What helped you to learn in this tutorial?'.

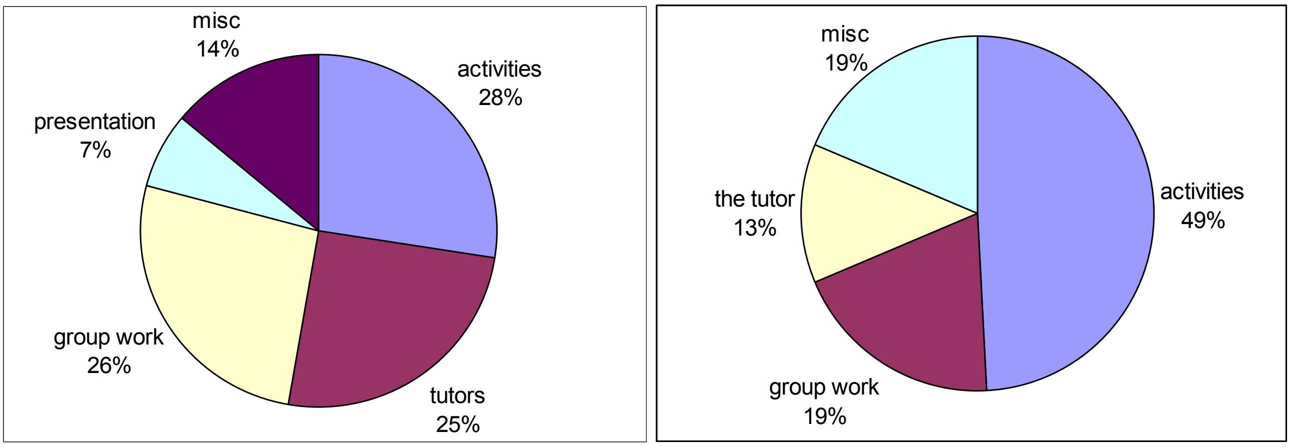

Figure 1. Results of minute papers. The chart on the left shows the responses by 127 primary education students at The University of Sydney to the question '*What helped you to learn in this tutorial?*'. In addition to the normal workshop tutorials as described in the text, the education students were required to give brief presentations at the end of each workshop. The chart on the right shows the responses from 110 bridging course students at the Cumberland Health Sciences campus of The University of Sydney to this same question.

The third question on the minute papers, 'What is one thing which is still unclear?', provided impetus to cover particular concepts again where a large number of students gave the same response. For example, in a bridging course, interference of light was identified as a particular difficulty and was addressed again, in more detail, in a later lecture. This had the added value of reassuring students that their time was not being wasted providing feedback which they would not see used.

In addition to the cognitive domain, students also indicated improvements in attitude due to the workshops. In the 'any other comments' space, a primary education student wrote '*I am really enjoying our interactive tutorials. Physics is becoming less of a chore and more of an interest*'.

Student focus groups were run by Tai Peseta of the Institute of Teaching and Learning at The University of Sydney. Tai was not connected with the tutorials or the Workshop Tutorial Project in any way, so that no bias would affect the results, and the students would feel free to give their opinions. The focus groups provide detailed information on the experiences in the workshops of a small number of students, in contrast to the 'snap-shot' view from a large number of students, as provided by the minute papers.

The focus groups provided some formative feedback on the organisation of the workshops, for example a need to increase the staff:student ratio for some sessions and timing problems with presentation of material in lectures and workshops. It also provided feedback on some minor changes to the tutorials during the semester, for example the introduction of large sheets of 'scribble paper' (butcher's paper) for groups to sketch diagrams, etc. The focus groups also provided valuable summative evaluation, as described below.

Summative evaluation of the Workshop Tutorials

The focus groups have been a useful form of summative evaluation for the workshops. In general the comments made by the students were very positive. They felt that the questions were at a suitable level, they enjoyed working in groups and also felt that they learned well that way. Student comments include: '*Qualitative questions are good – allows people to discuss their thinking processes*', '*Like group discussion – helps you to understand the concepts in different ways if each person in the group has a different way of arriving at a/the solution*'.

There is much interest in, and concern about, the 'first year experience' and the transition between high school and university. Many students feel lonely and alienated by the sheer size of the lecture classes in many first year courses. By ensuring that each student knows at least two or three others in their course, the workshops help to overcome some of these transition issues. It emerged from the focus groups that social networks outside of the workshops have formed from those initial groupings.

Another aim of the workshop tutorials is to teach generic skills, in line with the University's policy on graduate attributes. These skills include communication skills, the ability to work in a team, and 'life long learning' skills. One engineering student commented that '*the tutorials seem to be about learning how to learn*'.

The focus groups provided detailed information from a small number of students. To get a broader view of the students' experience of the workshops a survey was given to a large number of students at The University of Sydney, and the environmental physics students at the Australian Catholic University. The surveys were designed with the assistance of the Institute of Teaching and Learning to look at student learning, rather than just student enjoyment of the workshops. The survey used a five point Likert scale from Strongly Disagree to Strongly Agree. Again the results were largely positive with students indicating that they enjoyed the tutorials and that they found them a valuable learning experience. In particular they felt that the hands-on activities were a valuable learning experience, allowing them to apply knowledge they had learnt in lectures to real-life situations.

Use of evaluation to extend the project

The early evaluation of the workshops led to their expansion within the School of Physics from small remedial classes to a one hour per week component of all main stream physics courses in the school. A collaboration was then set up across The University of Sydney, the University of Western Sydney, the Australian Catholic University, University of Technology, Sydney and The University of New South Wales. This collaboration was successful in applying for a CUTSD grant to fund the Workshop Tutorial Project. The early evaluation which led to the grant is described in Sharma et al. (2001) and Sharma, Millar and Seth (1999). Without this initial evaluation phase the workshops would not have evolved, nor expanded, into their current form.

The collaboration across universities allowed the implementation of workshops for a broader range of students in a variety of settings, for example bridging courses. This gave the opportunity to evaluate the success of the workshops in these settings, and hence the portability and adaptability of the teaching development. The workshops were found to be easily transferable, with positive evaluation results in all settings. This is particularly encouraging, as many teaching developments are not easily transferable. McDermott's 'Tutorials in Introductory Physics' (McDermott and

Shaffer, 2002) have been extremely successful at the University of Washington, but are difficult to implement successfully without high levels of tutor training, and excellent tutor resources. Many other innovations, such as studio physics (Cummings et al., 1999), have been found too expensive for many Australian universities to run. In contrast, the workshop tutorials are relatively inexpensive and easily transferable. They have been successfully run with tutor:student ratios as low as 1 to 6 and as high as 1 to 30. The equipment used is generally inexpensive and easily obtainable, or consists of standard lecture demonstration items. This ease of implementation has allowed the implementation of workshop tutorials into several physics courses at The University of New South Wales and the Australian Catholic University, with other universities trialling the material including two universities from outside the initial collaboration.

Conclusion

Evaluation is necessary to judge whether a teaching development is worth pursuing or continuing. Any new development should be tested to see whether or not it actually does work, or work better than what was done previously. The success of teaching and learning grants is often measured by implementation into different courses and at other institutions. This is a challenging outcome which we have achieved within the two years of funding. Evaluation has been vital in achieving this outcome. Ongoing evaluation is necessary so that a teaching development can continue to evolve to meet the changing needs of students. Without ongoing evaluation the teaching development cannot adapt, and quickly becomes stale and out of date, ongoing evaluation is necessary for a teaching development to be sustained, and outlast the person or group who introduced the development.

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Reading Statistics

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Introduction

There has been a substantial increase in the cultural and academic diversity of commencing tertiary students over the previous decade. From 1990 to 2000 the total number of students in higher education increased by 43% (to just under 700,000), while the number of overseas students increased by a factor of four (to just under 100,000), raising the ratio to one-in-seven students (Department of Education, Science and Training, 2002). With this increase in number and cultural diversity comes an increase in their academic diversity. At the same time, changes in the nature and scope of professional work are placing an increasing demand on the range of skills, linguistic and numerical, that are needed by a successful graduate. A challenge for mathematics and statistics educators is the development of curriculum that addresses the language-related difficulties of language minority students, the numerical difficulties of students with diverse mathematical backgrounds, and enhances the learning outcomes for all students. This paper describes our approach to this challenge, based on our research in student conceptions of statistics and the language needs of professionals in the mathematical sciences, and embodied in the learning materials that we are currently developing.

Australian government and professional bodies have recognised the importance of this area. A recent review with a scope of ‘the 15 years from 1995–2010’, finds ‘unequivocal evidence that, as an economic and social instrument, advanced mathematical services relying on the mathematical sciences are critically important to Australia’ (National Committee for Mathematics, 1996). Recent government initiatives have targeted declining interest, standards and resourcing in mathematics (see for example Thomas, 2000). Similarly, universities are moving towards the integration of ‘generic skills’ within the curriculum, loosely equating statistical study with a higher-level ‘numeracy’.

Tertiary students in a wide range of areas will have need of statistics as a tool in their professional life. Many of them will find their first statistics course to be quite a shock, not only because it represents a completely new way of using numbers and language, but even because some of them had no idea that statistics would be a component of their studies. Yet, future researchers and professionals in many areas will need at least a working knowledge of the meaning of statistical outputs, and some may need to develop sophisticated understanding of statistics. The first statistics course has been much studied by statistics educators. Research on students’ learning in statistics has focused on the educational effects of approach, learning environment, materials and assessment (e.g. Roiter and Petocz, 1996; Petocz, 1998b; Garfield and Gal, 1999; Keeler and Steinhorst, 2001). Some research looks at the effects of students’ attitudes towards the subject (e.g. Gal, Ginsburgh and Schau, 1997), or their statistical ideas, particularly in the area of probability (e.g. Wild and Pfannkuch, 1999; Chance, 2000). A few studies have looked at students’ own conceptions of mathematics (Crawford et al., 1994) or of statistics (e.g. Reid and Petocz, 2002) and how this influences their learning.

Other research has focused on communication needs of future professionals in the mathematical sciences (Wood, Smith and Baynham, 1995; Coutis and Wood, 2002) and the development of appropriate curriculum to enhance students’ language abilities in this area (Wood and Perrett, 1997). The theoretical basis for these studies can be found in the ideas of critical discourse analysis (see e.g. van Dijk, 1998). The notion of helping students develop their language skills in the context of a particular subject area such as statistics is not new. However, what is new is the linking of our research into learning statistics with a theory of the relation between discourse and social factors. Moreover, this approach can be applied in any other area of science, and is not limited to statistics.

The research background

Our approach to the challenge outlined in the introduction is based on four theoretical frameworks. The first arises from a study of students' conceptions of statistics carried out by Petocz and Reid (2001, 2002) based on the phenomenographic approach (Marton and Booth, 1997). They found that statistics major students have qualitatively different ways of understanding statistics and learning in statistics, ranging from limiting to expansive views. Students who describe the most atomistic and limiting views seem only to be able to focus their attention on fragmented and unrelated components in their learning environment. Conversely, students who describe the most integrated and expansive views are able to make use of a wide range of learning approaches to further their already sophisticated understanding. Reid and Petocz (2002) introduce the abstract notion of the 'Professional Entity' – a way of thinking about students' (and teachers') understanding of professional work (based initially on studies in music, see Reid, 1997). It consists of three different levels: the *extrinsic technical* level describes a perception that professional work is constituted as a group of technical components that can be used when the work situation demands it; the *extrinsic meaning* level describes a perception that professional work is about developing the meaning inherent in discipline objects (e.g. data, in the area of statistics); and the *intrinsic meaning* level describes the perception that professional work is intrinsically related to a person's own personal and professional being. The significance of the Professional Entity is that there are specific conceptions of teaching and learning associated with each of its levels: a particular way of viewing the world of professional statistics corresponds to a particular approach to teaching and learning.

Moreover, teachers can help students move beyond the more limiting conceptions towards the broader conceptions. Reid (1997) has shown that teachers' approach to their teaching and the sort of learning environment that they set up in their classes can encourage students who identify with the lower, fragmented levels to engage with their learning at a higher level. However, this can also work the other way if a teacher sets students tasks that are best carried out using the more fragmented conceptions of learning (Reid, 2000).

The second framework on which our work is based is the theory of critical discourse analysis, particularly the ideas of Fairclough (1992, 1995). Critical discourse analysis 'studies the way social power abuse, dominance and inequality are enacted, reproduced and resisted by text and talk in the social and political context … critical discourse analysts take explicit position, and thus want to understand, expose and ultimately to resist social inequality' (van Dijk, 1998). Within the overall aims of critical discourse analysis, there are a diversity of theoretical frameworks. In the British context, the writings of Fairclough focus on various dimensions of power. He (and others) argue that there has been a large-scale restructuring of employment with major implications for the linguistic demands of work. The modern workplace is requiring more interpersonal communication skills, as the emphasis shifts from isolated workers to teams. A transformation is also occurring within the professions, where clients are no longer expected to adapt to the professional discourse: rather, the professionals are adapting to the language needs of their clients. In our experience, the situation seems no different in the Australian setting. We have found it useful to consider Fairclough's three dimensions of critical discourse analysis (1992, page 11):

(a) description of the text (with 'text' interpreted widely, and including spoken words);
(b) interaction with the text, involving processes of producing and interpreting the text; and
(c) explanation of the interaction with the text, by referring to its social and discipline context.

This defines three levels at which students can work with text. We have used these levels in designing our learning materials.

Another research framework that informs the design of our learning materials is the increasing emphasis on graduate profiles, professional competencies and generic skills (see e.g. Bowden and

Marton, 1998). Universities and professional societies are agreed on the importance of fundamental professional skills, or 'graduate competencies', that help to prepare students for an increasingly uncertain future. The development of academic and professional discourse skills ('communication skills') accords well with the capabilities needed by all graduates, but is sometimes lacking in graduates of quantitative disciplines. The siting of the language of the professions within informal language when dealing with clients, and within formal language when dealing with colleagues places extra importance on the diverse communication skills needed by graduates.

The fourth framework that we have used connects the ideas of equity, equal opportunity and non-discrimination which have become an explicit part of teaching and learning at university. For many lecturers, these are principles to which they have always adhered. However, the changes have been in the legislative and social acceptance of these principles. It is widely accepted that universities are no longer only for an elite, and importance is given to teaching and learning initiatives that are inclusive and that assist students to reach their full academic potential whatever their background. An extract from the University of Technology, Sydney's Equity Plan 2000-2003 (UTS, 2002) states: 'UTS is committed to the right of all students to study and access services in a university environment which is equitable, free from discrimination and harassment, and in which everybody is respected and treated fairly. A central objective of the UTS Mission Statement is *to improve educational provision for students from a diversity of backgrounds*'. We believe that good curriculum design that develops academic language skills and statistical skills meets the requirements of such an Equity Plan.

Curriculum design

Our focus in this paper is on enhancing language, numeracy and communication skills in culturally and academically diverse student cohorts, using the results of our research on student learning and communication needs. We have designed a flexible curriculum that uses real sources (published journal articles, conference papers, academic subject notes, e.g. Barron, 1997; Hunsaker and Ramsey, 1995) from the disciplines of the participating students. In our learning resource, *Reading Statistics*, we have examples from the areas of tourism and sport, environmental science, medicine and the health sciences, music, physical sciences, engineering, education and orthodontics. In each example, the source material is the basis of a series of questions focusing on the language of the article and the statistical aspects of the study. Although our questions do not neglect the lower-level skills, they are designed to encourage students to use the highest level of the taxonomy of discourse, and to view the subject material at the most expansive and holistic level statistically. These teaching and learning experiences can be adapted to any situations where students need to interpret and understand statistical material – the typical situation that many students in 'servicing statistics' courses will find themselves. They are encouraged to develop critical reading skills and understand the statistical content of research papers. They are also supported in making connections between the topics of the articles and their own personal and professional life.

Previously, we have been involved in preparing a range of learning materials that aim to extend students' ideas about the nature of statistics and mathematics, and to develop their communication skills in these areas. Such materials include textbooks (Petocz, Petocz and Wood, 1992; Wood and Perrett, 1997), video packages (Petocz, Griffiths and Wright, 1996; Wood, Petocz and Smith, 2000) and laboratory materials (Petocz, 1998a). In discussing the preparation of *Reading Statistics*, we are making explicit the theoretical background on which our approach is based, showing how we use our and others' research to prepare materials that will enhance the skills of our diverse groups of students. We are also allowing for the possibility of designing a whole statistics course that is built around the use of a series of readings in applications of statistics (see e.g. Roiter and Petocz, 1996).

Examples from *Reading Statistics*

We will give examples of the structure of the material in *Reading Statistics*. Each of the sources or readings is followed by a set of questions that direct students' learning, organised under two main headings, 'reading and comprehension' and 'statistics'. This is for convenience only, and it is not our intention to divorce the two aspects. The introductory questions are the same for all the readings, and these are followed by questions focusing on specific aspects of the source document. The questions for the reading sections were adapted from Wood and Perrett (1997) and are attributed to Perrett. In general, the introductory questions for each reading cover the descriptive and technical aspects of the text and the statistical analysis. The specific questions address higher order skills: they ask students to generate text or analyses, and place them within a wider context, in their own discipline. (Note that the layout of the questions has been condensed for this paper.)

Reading and comprehension

Do these pre-reading activities: this will save time and help you get the most out of your reading.

1. Identify the background of the article: Who are the authors? What is the title? What is the name of the publication it appears in?
2. Set a timer for 5 minutes and skim through the article: Skim reading techniques help you deal with large amounts of material in a short time. Pay particular attention to the title, abstract, headings, diagrams and the first and last paragraphs. Get as good an idea as you can of what it is about in the time limit. Summarise the article in 3-5 dot points. In a work or study situation, you may not wish to proceed further as the article may not meet your needs at the moment. By having the 3-5 dot point summary, you will be able to locate the article quickly if your needs change.
3. Aim and audience: Now read the whole article carefully and answer the following questions. What is the authors' major aim in writing the article? What audience are the authors writing for?

Statistical aspects

Do the following activities to help you identify the reasons why the author has used the particular research design and statistical techniques.

1. Identify the research question: Write down the research question. How is it presented? Why has the author presented it this way?
2. Identify the research methodology used: Write down the research methodologies used. Is it an observational study or an experimental study? What sampling techniques are used (if any)?
3. What data are given in the article? How are the data presented or described?
4. What statistical techniques are used and why? List the statistical techniques used. Give a reason for using each of them. What clues do you get from these about the aim of the whole text?

Specific questions on 'Images of Hospitality' (Barron, 1997)

1. The author identifies three reasons why high attrition rates in hospitality courses are a problem. List these three reasons.
2. Barron presents the main results from his study in the form of graphs and tables. Write down some of the good features of the graphs and some of the features that could be improved. Use your ideas to prepare a graphic showing the information in one of the tables.
3. The editor of your university newspaper has asked you to write a 300 word review of this article, addressing the following questions: What did you learn from this paper? Are any of the conclusions surprising? Who has benefited most from the study, and why?
4. *Work in groups for this question.* Are there any possible ethical problems involved in asking students to fill in a questionnaire in formal class time under the supervision of the lecturer/author? Does it depend on the context or the subject of the questionnaire? What ethical guidelines does your institution have for questionnaires in this situation, and do you think they are reasonable? Discuss these questions from various points of view in your group. If you are working in a class situation, different groups could present different viewpoints and the whole class could debate them.
5. Do you think that you and your fellow students have realistic and positive views of working life in your chosen area or industry? Design a short (one page) survey either to find out the views of students in your area, or to find out what extra experience or information students would like about working in this industry.

Specific questions on 'Trumpet Playing' (Hunsaker and Ramsey, 1995)

1. List the reasons why the authors of the current article believe that previous studies were flawed. How have the authors set up their study to minimise the problems of previous studies?
2. The article mentions the 'popular instrumental literature'. List five features of popular literature as opposed to research literature, and give a brief example of each.

3. Let's look at some of the details of the t-tests used in this article. First, use the information presented in Table 2 to carry out the independent samples t-test comparing the heart rate increase for younger and older musicians (how many?). Write down the null and alternative hypotheses. Why have the authors used a one-sided test? Do you think a two-sided test would have been better, worse, or just as good? Give reasons for your answer. Now show how to calculate the mean difference between the two groups and the standard error of the mean difference. Then show how to find the t-value for the test, and the p-value that summarises the result.
4. Now look at the paired t-test in Table 1. It was carried out to compare the resting and playing heart rates for a group of trumpet players (how many?). Write down the null and alternative hypotheses. Discuss why you think the authors used a one-sided test. Show how the mean difference was calculated. What about the standard error of the mean difference? Can you show how to find the t-value for the test, and the p-value that summarises the result? You may find that you can't do this, or that you get a different result to the one given in Table 1. Can you explain what the problem is?
5. Hunsaker and Ramsey write: '*The mean heart rate during trumpet playing was found to be significantly higher than when resting. Also, when compared by age groups, younger players had a greater increase in heart rate than older musicians.*'. Think about the first of these results in terms of your own music making (or some other activity). Can you suggest a more useful research hypothesis than the one that the authors used? Is there a simple explanation for why younger musicians increased their heart rate more than older musicians? Again, can you suggest a more useful research hypothesis than the one used in the paper?

Conclusion

In this paper, we have described an approach to designing curriculum that results in learning materials and corresponding teaching methods that combine a focus on real sources from the students' own discipline areas with a flexible and varied approach to their learning. We have done this in response to the increasingly diverse linguistic and academic backgrounds of our students and the increasing demands placed on them as graduates in professional areas. We have also discussed the research framework that has informed our development of such learning materials: research on students' conceptions of statistics and learning statistics based on a phenomenographic approach, notions of the increasing importance of communication skills in the workplace from work in critical discourse analysis, the increasing emphasis on graduate profiles and generic skills, and the greater visibility of notions of equity in tertiary education.

A criticism sometimes levelled against phenomenographic research is that, while it yields a description of the range of ways of viewing a phenomenon (an 'outcome space'), it does not result in any practical outcomes. This paper provides a clear counter-example – a phenomenographic study extended to yield a practical outcome that can influence the course of student learning. While we have used this approach in the discipline area of statistics, the same approach can easily be applied to a range of subject areas.

When we were preparing questions at the highest levels of both the hierarchy of conceptions of statistics and the taxonomy of discourse, we often came up with very similar ideas for questions that focused on language and those that focused on statistics. Although there is no evidence that the theories underlying the two approaches are related, and the fact that they each have three levels is simply coincidental, they can result in the same types of high-level questions. When you consider the descriptions of the highest levels of discourse and statistical conceptions, this is not surprising since they both focus on placing the student in the context of their discipline and their personal connections with society. In this context, it is interesting to note that early studies using the phenomenographic method (e.g. Marton and Saljo, 1976) focused on different ways of understanding written text. This research lead to the identification of 'deep' and 'surface' approaches to learning, described in detail in Marton and Booth (1997).

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