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ABSTRACT

The science community has been trying to use computers in teaching for many years. There has been much conformity in how this was to be achieved, and the wheel has been re-invented again and again as enthusiast after enthusiast has "done their bit" towards getting computers accepted. Computers are now used by science undergraduates (as well as their peers in other disciplines) not necessarily to aid their learning, but rather as everyday tools for word processing (mostly), data processing (or at least presentation) and entertainment (in large quantities). They are also used to a considerable extent as mathematical modelers in computer laboratories and data loggers in experimental laboratories. Nevertheless, the use of computer systems by science undergraduates to aid learning and understanding is still very limited. When the Windows environments were first available, there was a time when it looked as though the homespun computer learning aid was a thing of the past. The preparation of programs with visual quality that matched that of the Windows system itself was quite definitely moving out of the enthusiastic academic's ability range. This had the potential advantage of having to rely on professionally produced materials, which would automatically result in better quality and less reliance on enthusiasts to implement the courses using the software. The consequences that some of us saw from this trend were the better embedding of good quality learning aids in courses, with resulting stability of use. While this has happened to some extent, there have been several counter influences. New development systems have appeared that can easily produce visually attractive materials. But even worse, there has been the steady development of the Web. While the Web has contributed many undoubted benefits to teachers--particularly in the management of their teaching--it has also contributed to the return of the enthusiast, with idiosyncratic teaching materials, often of poor pedagogic quality, that are promoted by those who should know better merely because they form part of the brave new World Wide Web. Couple this to the general

trend of the modern world that presentation is far more important than quality of content and it will become clear that the science student of tomorrow may be in for a difficult time. This is a time of increasing change within the higher education sectors around the world. In the United Kingdom, the CTI Centers which spearheaded the move to improve teaching and learning by informing and encouraging academics to question their materials and methodologies and to introduce new technology where appropriate have been replaced by Learning and Teaching Support Network Centers (LTSNs) which have a broader set of guidelines. These guidelines include greater considerations on the pedagogical issues of teaching and learning and as such are more in alignment with the role of UniServe Science in Australia. It is hoped that these changes will to some degree counter the trends described above, giving the science students of tomorrow a slightly easier time. Sections include: (1) "Can a Combination of Hands-On Experiments and Computers Facilitate Better Learning in Mechanics?" (Jonte Bernhard); (2) "Why Should On-Line Experiments Form Part of University Science Courses?" (Hugh Cartwright); (3) "Is There a Right Way To Teach Physics?" (Ian Johnston and Rosemary Millar); (4) "A Flexible Learning Approach to Numerical Skills" (Duncan Lawson); (5) "Formative Assessment via the Web Using ELEN" (Roy Lowry); (6) "Science at the Amusement Park" (Ann-Marie Martensson-Pendrill and Mikael Axelsson); (7) "CALFEM as a Tool for Teaching University Mechanics" (Matti Ristinmaa, Goran Sandberg, and Karl-Gunnar Olsson); (8) "Pollen Image Management: Using Digital Images To Teach Recognition Skills and Build Reference Collections" (Peter Shimeld, Feli Hopf, and Stuart Pearson); and (9) "UKESCC Earth Science Courseware Goes on the Web" (W.T.C. Sowerbutts). (YDS)

# CAL-laborate

***A collaborative publication on the use of Computer Aided Learning for tertiary level physical sciences and geosciences***

**October 2000**



**Learning and Teaching Support Network United Kingdom**

**UniServe Science Australia**

**Council for Renewal of Higher Education Sweden**

## Editorial

The Science community has been using, or trying to use, computers within teaching for many years. There has never been much conformity in how this was to be achieved, and the wheel has been re-invented again and again, as enthusiast after enthusiast has 'done their bit' towards getting computers accepted.

Computers are now used by science undergraduates (as well as their peers in other disciplines) not necessarily to aid their learning, but rather as everyday tools for word processing (mostly), data processing (or at least presentation) and entertainment (in large quantities). They are also used to a considerable extent as mathematical modellers in computer laboratories and data loggers in experimental laboratories. Nevertheless the use of computer systems by science undergraduates to aid learning and understanding is still very limited.

When the *Windows* environments were first available, there was a time when it looked as though the homespun computer learning aid was a thing of the past. The preparation of programs with visual quality that matched that of the *Windows* system itself was quite definitely moving out of the enthusiastic academic's ability range. This had the potential advantage of having to rely on professionally produced materials, which would automatically result in better quality and less reliance on enthusiasts to implement the courses using the software. The consequences that some of us saw from this trend were the better embedding of good quality learning aids in courses, with resulting stability of use.

Whilst this has happened to some extent, there have been several counter influences. New development systems have appeared that can easily produce visually attractive materials. But even worse, there has been the steady development of the Web. While the Web has contributed many undoubted benefits to teachers – particularly in the management of their teaching – it has also contributed to the return of the enthusiast, with idiosyncratic teaching materials, often of poor pedagogic quality, that are promoted by those who should know better merely because they form part of the brave-new-World Wide Web. Couple this to the general trend of the modern world that presentation is far more important than quality of content, and it will become clear that the science student of tomorrow maybe in for a difficult time.

This newsletter is brought to you at a time of increasing change within the higher education sectors around the world. In the United Kingdom the CTI Centres, which spearheaded the move to improve teaching and learning by informing and encouraging academics to question their materials and methodologies and to introduce new technology where appropriate, have been replaced by Learning and Teaching Support Network Centres (LTSN's) which have a broader set of guidelines. These guidelines include greater considerations on the pedagogical issues of teaching and learning and as such are more in alignment with the role of UniServe Science in Australia. We hope these changes will to some degree counter the trends we described above, and give the science student of tomorrow a slightly easier time.

**Dick Bacon** **Ian Johnston** **Ingemar Ingemarsson**

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# Can a Combination of Hands-on Experiments and Computers Facilitate Better Learning in Mechanics?

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## Abstract

Microcomputer-Based Laboratories (MBL) have been successfully used to promote conceptual growth in mechanics understanding among preservice teachers and engineering students. In MBL laboratories students do real hands-on experiments where real-time display of the experimental results facilitates conceptual growth. Thus students can immediately compare their predictions with the outcome of an experiment, and students' alternative conceptions can thus successfully be addressed. We also report from a case where only MBL-technology was implemented, but the students were not asked to make predictions. As a result "misconceptions" were not confronted and conceptual change was not achieved among "weak" students.

## Introduction

Acquiring a conceptual understanding of mechanics has proven to be one of the most difficult challenges faced by students (for a good overview see McDermott 1998). Studies by many different researchers have shown that misleading conceptions of the nature of force and motion, which many students have, are extremely hard to overcome. These strong beliefs and intuitions about common physical phenomena are derived from personal experience and affect students' interpretation of the material presented in a physics course. Research has shown that traditional instruction does very little to change students' "common-sense" beliefs (see for example McDermott 1998; Hestenes et al. 1992; Hake 1997; Bernhard 2000a).

For some decades sensors attached to a computer have been used in most experimental physics research laboratories. The attachment of a sensor to a computer creates a very powerful system for the collection, analysis and display of experimental data. In this paper I report on cases where hands-on experiments have been combined with a microcomputer-based system for the collection and display of experimental data. This MBL concept has proved to be a very powerful educational tool.

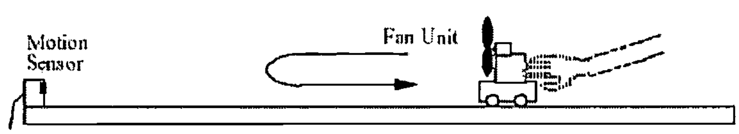


**Figure 1**. Typical setup of a MBL-experiment. A low-friction cart is pushed towards a motion sensor. A fan unit attached to the cart provides an approximately constant force in a direction opposite to the initial movement and the cart will thus change its direction of motion. The results are shown in Figure 2. Note that the fan unit provides a visible force.

Partial financial support from the Swedish National Agency for Higher Education, Council for Renewal of Higher Education, is gratefully acknowledged. Part of the research reported in this paper was done while the author was employed at Högskolan Dalarna, Borlänge, Sweden.

In an MBL laboratory students do *real* experiments, not simulated ones, using different sensors (force, motion, temperature, light, sound, EKG ...) connected to a computer via an interface. One of the main educational advantages of using MBL is the real-time display of experimental results and graphs thus facilitating direct connection between the real experiment and the abstract representation. Because data are quickly taken and displayed, students can easily examine the consequences of a large number of changes in experimental conditions during a short period of time. The students spend a large portion of their laboratory time observing physical phenomena and interpreting, discussing and analysing data with their peers. The MBL context adds capacity and flexibility that, to be exploited requires the laboratory to be reconceptualised, giving students more opportunity to explore and learn through investigations (Tinker 1996; Thornton 1997b). This makes it possible to develop new types of laboratory experiments designed to facilitate better student learning and to use laboratories to address common preconceptions. *To take full advantage of MBL the educational implementation is important, not the technology! Active engagement is important!*

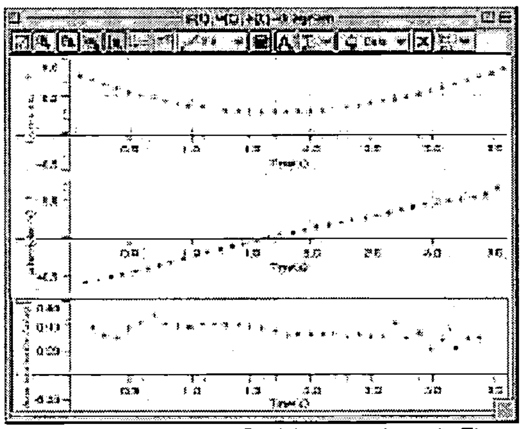

**Figure 2**. Results of the MBL laboratory shown in Figure 1. The position, velocity and acceleration as functions of time are displayed. A common misconception is that the cart has zero acceleration at the turning point. Another common misconception is that the acceleration is in the direction of motion (see the poor results on the pre-test for "coin acceleration" in Figure 4). By asking the students to make a prediction and sketch the *s(t)*, *v(t)* and *a(t)* graphs *before* the experiment and by the rapid display of the experimental results these misconceptions can effectively be addressed.

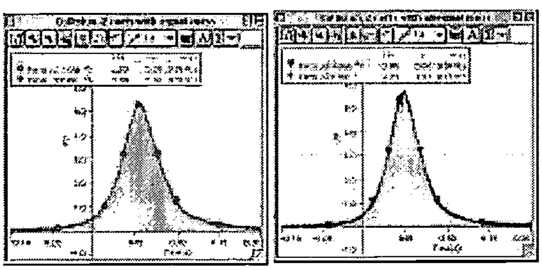

**Figure 3**. Results from an MBL-experiment with two colliding carts with equal and unequal masses respectively. Force sensors are mounted on top of each cart. The graphs show the forces measured by the sensors during the collision and the area below curves. Note the time scale. Most students are surprised to discover that the forces are equal when the carts have different masses (see "3rd collision" pre-test in Figure 4).

## Implementation of MBL laboratories

The physics department at Högskolan Dalarna started using MBL in 1994/95. Laboratories using MBL-technology have been introduced in most physics courses. Below will be described the results of implementations of MBL in "active engagement" mode (Cases 1 and 2) and in mainly "formula verification" mode (Cases 3 and 4).

### *Cases 1 and 2*

*Case 1*: An early implementation of MBL laboratories (Preservice teachers 1995/96) in a course for preservice science teachers (preparing for teaching grades 4–9 in Swedish schools). *Case 2*: A full implementation of MBL laboratories (Mechanics I 1997/98 for Engineering students) and some other reforms (see Table 1). This curricular reform also included changes to the advanced mechanics course (Mechanics II). The reformed advanced mechanics course is described elsewhere (Bernhard 1998, 1999). In both cases 1 and 2 there were about 40 students in the course.

The educational approach (Bernhard 2000b) taken in both cases was inspired by, but not identical to, the approach taken by Sokoloff et al. (1998) in *RealTime Physics* (see also Thornton 1997b, and references therein) and in case 2 also by the "New Mechanics" paper by Laws (1997). Laboratories were written in Swedish by the author.

- In both cases MBLs were used in an active engagement mode and the laboratories emphasised concepts and connections between different concepts.
- Case 1 had an early version of MBL laboratories and no laboratory on Newton's 3rd law.
- Cooperation was encouraged.
- Students preconceptions were addressed by asking the students to make predictions of the outcomes of all experiments (*elicit [student ideas]* - confront - resolve).
- After making predictions, the students performed the experiment and compared the outcome with the prediction (elicit - *confront* - *resolve*) and discussed the result. At this point the rapid display of the results by the computer in graphical form is of crucial educational value.
- Each laboratory group of 2-3 students was asked to submit a written report from each laboratory. This reinforces and strengthens student understanding, since they have to describe the laboratory in their own words.

### *Case 3: Preservice teachers 1998/99*

(~ 30 students)

- MBL-technology was used in the laboratories.
- The original laboratories were transformed into formula verification laboratories and the number of laboratories was reduced for economical reasons.
- The students were not usually asked to do predictions.
- No laboratory on kinematics.

### *Case 4: Preservice teachers 1999/2000*

(~ 25 students)

- Similar to case 3.
- The Newton's 3rd law laboratory was changed from "formula verification" to "active engagement".

| | |
|---|---|
| **Motion** | This laboratory introduces kinematics concepts using MBL and also uses the tutorial software *Graphs and Tracks I & II*. |
| **Analysis of motion using *Videopoint*** | Introduces two dimensional kinematics using *Videopoint*. |
| **Force and motion I & Force and motion II** | The force and motion laboratories use MBL-equipment to study dynamics (Newton's 1st and 2nd laws). Cases with friction and friction free cases are studied. |
| **Ballistic pendulum** | A ballistic pendulum is used to determine the muzzle speed of a ball fired by a projectile launcher. This is an "open" laboratory where the students are required to deduce necessary equations themselves. |
| **Impulse and collisions** | This laboratory uses the new PASCO force sensor to measure forces during collisions (Newton's 3rd law) and to experimentally study the impulse – momentum law. |
| **Moment of inertia** | This laboratory uses the rotary motion sensor to study rotary motion, moments of inertia and oscillatory motion (ideal and physical pendulums). To study physical pendulums and the parallel axis theorem (Steiner's theorem) we used equipment which was designed and manufactured at Högskolan Dalarna together with the rotary motion sensor. |

**Table 1.** Laboratories (4 hours) used in the Mechanics I course in 1997/98.

## Evaluation instruments

The *Force Concept Inventory* (FCI) developed by Hestenes et al. (1992) and the *Force and Motion Conceptual Evaluation* (FMCE) developed by Thornton and Sokoloff (1998) were used as instruments for evaluating students' conceptual understanding. The data from the FMCE-test were analysed using the *Conceptual Dynamics* method developed by Thornton (1997a). Using this method, student views (for example force-follows-velocity view or physics view) can be assigned.

## Results

### *Cases 1 and 2*

As can be seen in Tables 2 and 3 and in Figures 4 and 5 the students in cases 1 and 2 have gained a much better conceptual understanding of mechanics than students in traditionally taught courses. A high fraction of the students have acquired a Newtonian view and a low fraction of students hold a force-follows-velocity view after instruction. The students in Mechanics I (case 2) performed significantly better on traditional problems in the final examination, than the students did in earlier similar courses.

In this course male and female students also had the same normalised gains.

| Course | Year | Main student body | Method | Pre-test average | Post-test average | Gain (G) | Normalised gain (g) |
|---|---|---|---|---|---|---|---|
| Preservice | 95/96 | Preservice science teachers (grades 4-9) | early MBL | 50% | 71% | 21% | 42% |
| Mechanics I | 97/98 | Engineering | Full MBL + | 51% | 73% | 22% | 45% |
| Preservice | 98/99 | Preservice science teachers (grades 4-9) | MBL-technology Formula verification | 49% | 65% | 16% | 31% |
| Preservice | 99/00 | Preservice science teachers (grades 4-9) | MBL-technology Some MBL pedagogy | 35% | 67% | 32% | 49% |
| Traditional | 97/98 | Engineering | Traditional | 50% | 58% | 8% | 16% |

**Table 2.** Results of pre- and post-testing using *Force Concept Inventory* (Hestenes et al. 1992) on different student groups. Gain (G) = post-test – pre-test. Normalised gain (g) = gain / (maximum possible gain) (Hake 1997).

| Course | Year | Main student body | Method | Pre-test average | Post-test average | Gain (G) | Normalised gain (g) |
|---|---|---|---|---|---|---|---|
| Mechanics I | 97/98 | Engineering | Full MBL + | 29% | 72% | 43% | 61% |
| Preservice | 98/99 | Preservice science teachers (grades 4-9) | MBL-technology Formula verification | 33% | 53% | 20% | 30% |
| Preservice | 99/00 | Preservice science teachers (grades 4-9) | MBL-technology Some MBL pedagogy | 27% | 62% | 35% | 48% |

**Table 3.** Results of pre- and post-testing using *Force and Motion Conceptual Evaluation* (Thornton and Sokoloff 1998) on different student groups. Gain and Normalised gain defined as above.

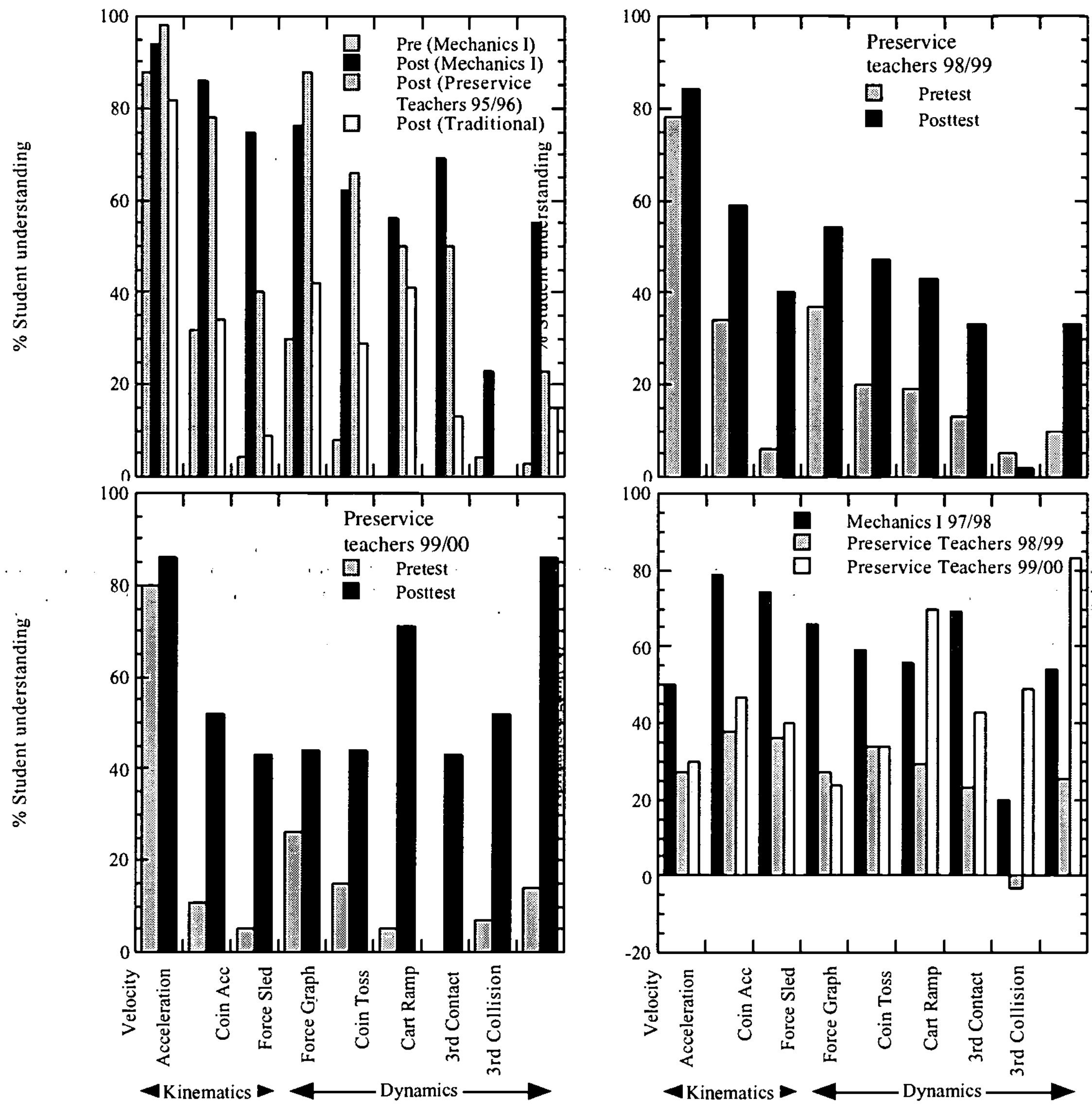


**Figure 4**. Conceptual understanding in mechanics as measured by the FMCE-test.

### *Case 3*

The students in case 3 did not perform as well as in cases 1 and 2, but somewhat better than students in traditionally taught courses did. As can be seen in Figure 5 almost the same fraction of students hold the force-follows-velocity view after instruction as before instruction. By eliminating the active engagement part from the laboratories the preconceptions of the students believing in this view were not reached.

There were also large differences in gains between male (higher gain) and female (lower gain) students. A higher fraction of female students believed in a force-follows-velocity view after the course than before instruction!

### *Case 4*

The students in case 4 performed similarly to the students in case 3, except for a much better performance in the Newton's 3rd law conceptual areas (see Figure 6 below). The difference in gains between male and female students was smaller than in case 3.

## Discussion and conclusions

Microcomputer-Based Laboratories (MBL) in an active engagement approach is proven to be an effective way of fostering conceptual change in mechanics. The conceptual understanding is long-lived (Bernhard 2000c). MBL is good both for preservice teachers and engineering students. The combination of hands-on experiments and the microcomputer-based measurement system is a very powerful educational tool and according to Euler and Müller (1999) one of the few educational approaches in physics using computers which is reported to have positive effects on student learning. Students need to make use of as many senses as possible in their meaning making and thus approaches which make use of both hands-on and high-technology tools seem to be very effective (see also Otero 2000). In a well implemented MBL-approach MBL is used as a technological tool and a cognitive tool.

However the MBL-approach can be misunderstood and implemented as a technology only approach. When implemented without sound pedagogy, MBL is only marginally better than "traditional" teaching. Pedagogy is more important than technology! The personal preconceptions students hold before instruction *must* be addressed in some way during a course. Asking students to make predictions before an experiment is done is one way to both confront "misconceptions" and to reinforce scientific views.

It is also very important to focus on the teacher's pedagogical views since they can distort/destroy the implementation of an educational approach (see also for example Sassi 2000). Probably it is as difficult to change a teacher's view/conception of teaching, as it is to change a student's view/conception of the world.

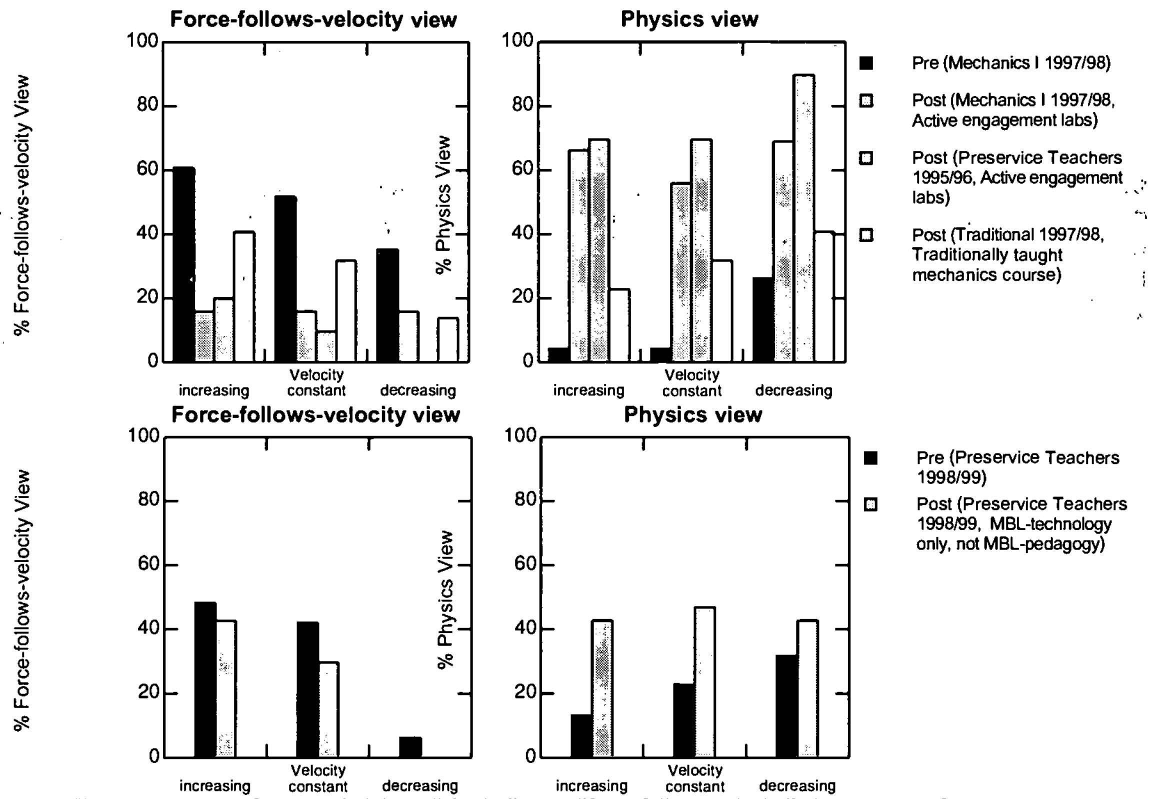


**Figure 5**. Fraction of students holding a "physics" and a "force-follows-velocity" view extracted from FMCE-test data using the Conceptual Dynamics Method.

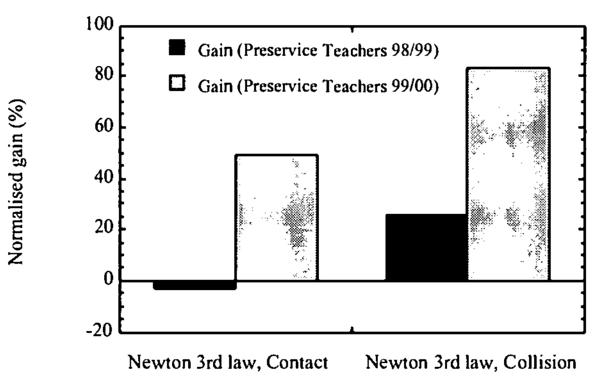


**Figure 6**. A comparison of Newton's 3rd law data from the FMCE-test for Preservice Teachers 98/99 and 99/00. Both groups had a laboratory dealing with Newton's 3rd law of the same length and with the same MBL-equipment. However the laboratory used by Preservice Teachers 98/99 was a formula verification laboratory and the 99/00 group "active engagement".

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# Why Should On-line Experiments Form Part of University Science Courses?

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## Introduction

Just as in government, it seems that there are always "buzz words" in teaching. In many Western countries the present favourites include "Lifelong Learning" and "Distance Education", reflecting the view that education should be universally available to students, irrespective of age and location. The importance of Lifelong Learning and Distance Education is apparent in an increasing number of articles published on these issues, and a bias in European Union funding devoted to research into them. Much progress has been made in recent years; one might (perhaps cynically) suggest that an increase in the number of published papers is an inevitable consequence of increased funding, but the growing interest in these areas is also a consequence of a widespread recognition that they are areas of genuine importance.

The principle catalyst for the expansion of distance learning has been the evolution of the Internet. Internet-based learning can take place anywhere, provided that access is provided to a computer, telephone and modem, and such access is, of course, now common in the Western World. If learning is to be effective, there must be suitable teaching material available on-line, but most scientists are computer-literate, and many have been quick to develop web-based material. As a result, the quantity of on-line science tutorials, databases and auxiliary materials, such as interactive periodic tables, is now very considerable. Because of the ease with which subject matter can be "published" on the Web and the general lack of peer review, on-line material is not always of the highest quality. However, there is much which is accessible, authoritative and well-constructed, and the quantity of this in scientific areas is now such that one could study substantial portions of a chemistry degree course entirely on-line.

It is inevitable that distance learning will continue to grow in importance as access to the Web broadens. Web-based material offers advantages in speed of delivery, flexibility and cost, and schools and universities will increase their use of electronic information because of this. However, a crucial ingredient is missing from on-line science: there is almost no opportunity for students to carry out experiments – as opposed to interact with simulations – through the Internet. In subjects such as physics and chemistry, which are inherently experimental, this is a serious limitation.

To develop the broadest possible understanding of science, it is important that students can experience the practical side of the subject, even if they have no direct access to a laboratory. The Internet offers the chance for remote learners to study the principles of science on-line, but it can also provide the means by which they can carry out practical work. Similarly, the Internet will allow practical courses for those students who are taught in more traditional surroundings to be enhanced. The potential and practicalities of experiments conducted over the Internet form the topic of this article.

## The need for on-line experiments

We shall start from two assumptions:

- that carrying out real (as opposed to simulated) experiments can materially enhance understanding for students, so practical experiments should whenever possible be a component of science courses; and
- that the Internet provides a convenient and effective medium by which experiments can be made available to students.

Our view in this article is that Internet-based experiments are entirely feasible, and that they offer a range of significant advantages. A subsequent paper will discuss the software implementation of on-line experiments, and the details of how they may be integrated into a traditional practical course.

Of the two assumptions given above, we shall not try to justify the first – that experiments can enhance scientific understanding. Science is based upon experiment, and while it is entirely possible to study fundamental areas of science, such as quantum mechanics or nuclear physics, without ever completing an experiment, in even these areas theory is generally tested by comparing theoretical prediction with experimental results. Universities and colleges recognise implicitly the value of experiment by making practical courses an integral part of their degree courses. It is reasonable to suppose that experimental aspects of science do not somehow become of lesser importance if the course is delivered remotely. It follows that experiments are of as much educational value to distance learners as they are to traditional, university-based learners.

The second assumption, that the Internet might provide a suitable medium through which to conduct experiments, requires more justification. Although the Web was not designed to support interactive experiments, the rapid increases in speed of network communication now offer the possibility of carrying out sophisticated experiments, and a later article will show how effective the Internet can be as a medium for the delivery of on-line experiments.

We will not discuss individual experiments in detail here, but will present some of the reasons why, in the near future, universities, colleges and schools may find it desirable to use the Internet to enhance their practical courses.

## Advantages of Internet-based experiments

Internet-based experiments offer advantages to both learner and institution; we consider here some of the more important benefits.

### *Access to experiments for remote learners*

Many students study university or college level courses remotely, perhaps because they have a job and are unable to enrol as full-time students, because they lack the necessary qualifications, or because they find part-time study more attractive than a full-time course. The Open University in the United Kingdom, and equivalent institutions in other countries, have a very large constituency of students, illustrating how attractive such remote courses are.

At present, home-based students can carry out only a limited range of (generally unsophisticated) experiments at home, although these may be supplemented by an occasional residential stay at university, during which experiments which require more substantial equipment may be performed. The Open University recognises the value of experiment in many of its excellent science courses by both providing kits of experiments which science students can use at home, and by offering university-based summer schools at which students can undertake experiments which are not possible at home. If it were possible for these students to carry out experiments through the Internet, there could be a significant increase in the range of experiments which they could perform. In addition, experiments which require sophisticated equipment could be integrated into the course in a more timely manner, and performed by students when the relevant theory was being studied, rather than having to be carried out during a residential summer school, when theory and experiment might be separated by several months.

### *Expansion of university and college practical courses through the sharing of experiments*

At most universities the practical courses in chemistry are, especially in physical chemistry, a compromise. There is an (often substantial) wish-list of experiments which those running the course would like to offer. A somewhat smaller number makes up the list of experiments which can actually be provided. Time, space, finance and available expertise may serve to limit the number of experiments which can be made available to students, and at almost every institution there are experiments which, while educationally valuable, cannot be offered. A small number of students may visit neighbouring universities to carry out experiments which are not available in their home institution, but this kind of sharing is difficult to organise, and is of benefit only if co-operating institutions have courses which do not overlap excessively.

If experiments are available through the Internet, instead of students going to the experiments, the experiments can come to the students. The range of experiments can be increased, and, if an experiment which a department is unable to provide themselves is available remotely, the practical course can be expanded at negligible cost.

### *Avoidance of duplication of equipment*

In chemistry, and also in physics, identical or similar experiments are found in the undergraduate practical courses in many different universities. A glance at the contents of practical courses in physical chemistry in the United Kingdom suggests that most chemistry undergraduates have the chance to measure the high-resolution infrared spectrum of HCl and DCl, the visible spectrum of gas-phase iodine molecules, the enthalpy of combustion of an organic solid, the kinetics of an iodination reaction and so on. Every university has its own slant on the chemistry practical course, but there is much overlap between courses at different universities.

This is to be expected. The HCl/DCl spectrum is a valuable way of illustrating selection rules, the determination of molecular parameters from spectroscopy, the effect of temperature on spectra and more. Experiments which are effective at illustrating the lecture course at one institution are likely to be of similar value elsewhere. However, when so many institutions are running similar or identical experiments, a considerable duplication of equipment is inevitable. One might regard this duplication as an inefficient use of resources, made more difficult to justify by the fact that much equipment purchased for undergraduate chemistry courses is used moderately during term-time, but hardly at all out of term.

Sharing of resources amongst universities is – at least in chemistry in the United Kingdom – at a low level. This need not be so. If nearly identical experiments and equipment are used in two or more institutions, could not both experiment and equipment be shared through the Internet?

There are of course experiments for which this might be difficult or undesirable. For example, it might be important that students be present as measurements are made, so that they can learn how a spectrometer actually operates; students might need to perform some preliminary part of the experiment, such as the synthesis of DCl before a spectrum can be recorded; unwanted complexity might be introduced into experiments by the need to provide remote access; it may also be difficult for a student to modify the procedure for an experiment if he or she has no physical access to the equipment.

For these, and other, reasons, it is unlikely that departments would want to run all or even most of their experiments through the Internet, but a class of experiments, outlined below, are eminently suitable for on-line operation.

At a time when universities and colleges are under considerable financial pressure, the chance to maintain or expand the practical course, but at the same time to reduce its cost, should be attractive to many.

### *Access to equipment in remote or hazardous locations*

Much fascinating science is observed only under extreme conditions. The interaction of subatomic particles in nuclear physics experiments is an obvious example, but there are also examples in chemistry, where studies of reactions at high temperature, under high pressure or under conditions of zero gravity tell us much about the way molecules behave. The conditions required for these experiments may be difficult, dangerous or expensive to create, but this in no way lessens the value of the experiment. Indeed, sometimes extreme conditions are most effective in testing and validating scientific theory.

If students can rarely visit other universities to carry out experiments, it is even more unusual for them to have access to the specialised facilities which would allow experiments under extreme conditions to be carried out. Remote access, however, brings with it none of the dangers which direct access might provide, and often the very nature of the extreme conditions makes this kind of experiment more interesting to the student. It can be challenging to get some students involved in the practical course, and the chance to perform experiments under exotic conditions may be just the sort of stimulus required to awaken the interest of such students.

### *Sharing of experiments between students*

Group work is a valuable way of improving understanding and retention of information. In many universities, especially in the USA, group projects are a popular way to promote scientific learning, and in most universities a similar approach is taken in the practical course. Experiments are commonly performed by pairs or small groups of students, not only because this increases the number of students who can complete each experiment, but also because interpretation of data and the preparation of a report often benefits from students being able to discuss the experiment with their colleagues.

Such cooperation need not be limited to those working at a single site. Cooperation between students at different sites is becoming very much easier now that email is virtually instantaneous. If students have worked on the same experiment on-line, or have worked on different aspects of a single problem using an identical piece of on-line equipment, this kind of long-distance cooperation becomes a realistic option.

### *Ability to provide a more custom-built practical course for students*

Laboratory space is limited, and so inevitably is the range of experiments which a given university can provide. In the lecture-based segment of courses many institutions offer a modular course which allows the student to design a course which (they believe!) best meets their own interests. It is more difficult to do this in the practical course, where the range of experiments may be smaller, and where typically the course may be strong in some areas of chemistry and weaker in others. There is not total agreement that modular chemistry courses are educationally preferable to courses designed along more traditional lines, but if a department believes that a wide menu of lecture courses is in the best interests of the student, they may feel that a broad spectrum of experiments is equally desirable. The augmentation of local experiments by the addition of a range of Internet-based experiments, widens the options available to students and allows a more personalised course to be built.

## What kinds of experiments can be run through the Internet?

The advantages which Internet-based experiments offer are, I believe, substantial. The pressures to develop them, particularly financial pressures, are similarly strong, and it seems likely that there will be widespread access to web-based experiments within the next five to ten years. Indeed, considering the extraordinary rate at which the Internet has developed, it seems inevitable that such experiments will be pervasive within a few years. However, not every experiment is a candidate for on-line format, and we conclude with a brief consideration of the sort of experiment that could best be delivered over the Internet.

Some types of experiments are evidently poor candidates. It is possible to perform titrations remotely using an auto-titrator, but much of the educational value of performing a titration is learning the physical skills involved. Locating an end-point is easy if a machine does it for you. Furthermore, an on-line titration suffers from a potentially costly drawback, which will prevent many experiments from being made available on-line. Titrations consume chemicals, so on each occasion that an on-line titration is run there is an unavoidable cost to the hosting institution. Furthermore, even if the cost of chemicals can be absorbed, a titration experiment cannot be run indefinitely without operator intervention – someone must ensure that stocks of chemicals are maintained. It is a simple matter to run an on-line experiment in such a fashion that only Internet connections from certain sites are allowed, but it seems likely that on-line experiments which consume significant quantities of reagent will not play an important part in practical courses for some time, and probably will always, when available, have restricted access.

Equally, universities may be reluctant to offer experiments in which mechanical equipment can be switched on and off by remote users. There is no difficulty in principle in arranging that a remote user should be able to turn on a vacuum pump, for example, but a pump may seize or overheat, and this clearly has safety implications.

Ideal experiments thus appear to be those in which chemicals are not consumed in any significant quantity, and which can safely be left running indefinitely at low or zero cost. Several types of spectroscopy experiments fall in this category, and are perhaps the most attractive candidates for on-line operation. IR or UV/visible spectra can be run on instruments equipped with sample changers, and MS (mass spectrometry) experiments on systems with auto-injectors. In addition, cyclic voltammetry experiments, some of which can be run repeatedly without a change in solution, can also readily be placed on-line at minimal running cost.

An on-line experiment at Oxford University, currently being upgraded by the installation of new software, is used to generate data for use in an experiment on error analysis[1]. The experiment, which is spectroscopy-based, has no moving parts, and can operate continuously without any operator intervention. The detailed implementation of this experiment is to be the subject of a later article.

On-line experiments are in their infancy. Like everything connected with the Internet, they are likely to become a routine part of teaching much earlier than one imagines. They may well also have a rather different form in five years from what one might at present envisage. In whatever form they appear, their widespread adoption seems inevitable, and close at hand. In view of the considerable advantages they offer, those of us who are involved in the teaching of practical physical chemistry should welcome their arrival.

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# Is There a Right Way to Teach Physics?

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## Background

An important development in university physics teaching in the last two decades has been the emergence of a world-wide Physics Education Research community. In physics departments at relatively large numbers of institutions throughout the world, particularly the USA and Europe, academic physicists are doing research into the difficulties associated with teaching their subject[1]. Among the many directions this research has taken is the identification of "misconceptions" (sometimes referred to as "alternative conceptions"). These are ideas or concepts which students have constructed for themselves, based on their own experience of the natural world, which are often in conflict with the agreed view of practicing scientists. Research has shown that these "misconceptions" are very widely shared, very often in conflict with other concepts the student holds, and very difficult to change.

Following on from this research, as it were, a lot of work has been done to develop special diagnostic tests to uncover which, if any, of these misconceptions particular students hold. They normally consist of series of multiple choice questions, in which the "right" answer is hidden among very tempting distracters, each one targeting one or more common misconceptions. Among the best known of these tests, in the subject area of kinematics and dynamics, are the *Force Concept Inventory* (FCI)[2] and the *Force and Motion Conceptual Evaluation* (FMCE)[3].

This research has, in turn, prompted the development of teaching strategies which target specific classes of misconceptions — in the (understandable) belief that, if students can get the fundamental concepts "right", they have a better chance of understanding the rest of the subject. The results of these strategies are reported in the literature, and there is coming to be a consensus within the physics education community that, for example, traditional (chalk and talk, lectures plus laboratories) teaching is relatively ineffective in changing misconceptions. On the other hand, one recent survey of over 7000 students in the USA has shown that teaching which employs interactive methods can result in significant increases in understanding (as measured by these diagnostic tests).[4]

It would seem important therefore that teachers everywhere should take these findings seriously, and, where possible, test whether the same gain in understanding can be achieved in other teaching contexts.

## Interactive Lecture Demonstrations

Many of the new techniques just mentioned involve quite elaborate teaching materials and preparation time on the part of the teacher. In today's university climate, increasing workloads and student numbers often mean that time is just what university teachers do not have. Therefore many of these new techniques are destined to be little used. However, one particular new technique, which originated at Tufts University, Boston, involves the use of *Interactive Lecture Demonstrations*[5], and is designed to be used in a traditional teaching context, that is in an ordinary lecture. ILDs consist of a number of simple experiments which use a microcomputer to log data from a motion sensor, and to display it in graphical form on a data projector, while the instructor performs a number of simple "experiments". Students are told what is going to happen, and write their predictions of what the graphs will look like on specially prepared sheets. Only when they have done this and resolved any disagreements, by discussions among themselves, are they shown the actual experiment and the data the computer has collected and graphed. After this, class discussion is devoted to where any incorrect predictions went wrong.

Clearly such a technique means that the instructor must follow a pretty rigidly imposed scenario. Although the demonstrations are done in an ordinary lecture setting, there is little scope for the instructor doing what he or she wants to do. Questions of "covering the syllabus" and "giving good sets of notes" have to take second place. Luckily there are only four one-hour sessions specified, and the instructor has the rest of the allotted periods to do what is normally considered necessary in a lecture course (and which, it will be remembered, research shows to be not very useful).

Results from this teaching technique have been reported in the literature over the last five or six years. Typical are those reported from the University of Oregon in 1996, shown in Figure 1[6]. The diagnostic instrument used was the FMCE, and student responses are reported for four groups of questions concerning Newton's Laws, though it is not particularly relevant what material the questions covered.

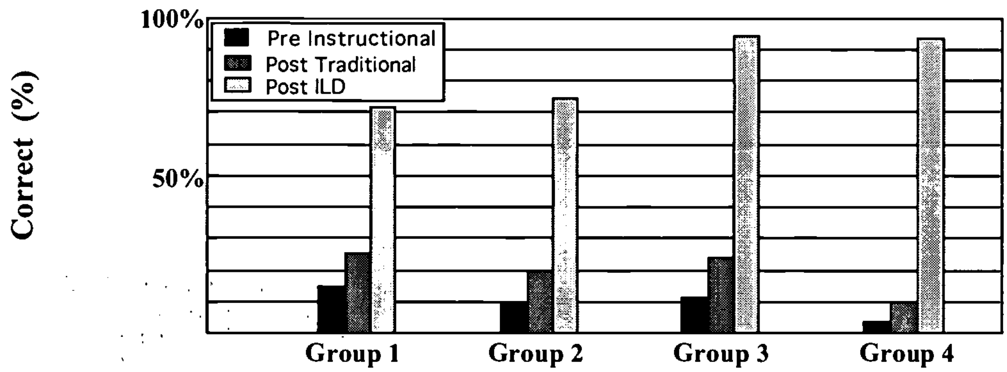


**Figure 1**. Showing the percentage of correct responses to questions in four groupings, as published by Thornton and Sokoloff. Results are (1) responses from students in all classes **before** instruction, (2) responses **after** instruction from classes taught by traditional methods, and (3) responses **after** instruction from classes taught using ILDs. The figure is adapted from reference.

Several points will be noticed from this figure. Firstly that student "understanding" (or whatever is being measured by these tests) is very low on entry. It must be noted that the physics course in question was calculus-based, and the students would be planning on a physics major. Some of the more prestigious universities in the USA have students who attain higher scores on entry, but nevertheless, scores similar to the above are not untypical of students just out of high school in the USA.

Secondly it will be noted that there is no very great improvement after a semester of traditional instruction. Such results are also typical of universities and colleges reported in the literature, and are part of the accepted body of evidence which suggests that traditional teaching is relatively ineffective in generating this kind of understanding.

Lastly there is the very impressive improvement in "understanding" demonstrated by those students who were exposed to four one-hour sessions using the ILDs and the stipulated interactive teaching. The results reported here are not the only ones who show such improvements. Therefore this particular teaching technique seems able to claim, *prima facie*, to be one which promises that other teachers can expect similar improvement. It would obviously be important to test this expectation in another context — for example, with a class of Australian students.

## Evaluating the effectiveness of ILDs

In March 1999, such a test was held with physics introductory students at The University of Sydney. The roughly 450 physics students were divided into four calculus-based classes, one at the "Advanced" level and three at "Regular". Of the latter, one group was taught using ILDs, and the other two, taught by a different lecturer, were regarded as a control. The structure of the course is similar to most physics departments in the country. The areas of kinematics, force and motion, work and energy, collisions, rotational dynamics are taught over five weeks, usually by 15 one-hour lectures with a weekly tutorial and regular homework assignments. For the trial being reported, the experimental class had 11 one-hour lectures and four one-hour ILD sessions, but everything else was the same. All classes shared the same assignments and end-of-semester examination.

All 450 students were tested during the first lecture period, using the MPCE diagnostic test, and two weeks after the end of the module, in the seventh week of semester, all were asked to take exactly the same test again.

## Results

Results of the experiment are shown in Figure 2, in which student responses are reported for ten groups of questions on that test, including the four groups singled out in Figure 1.

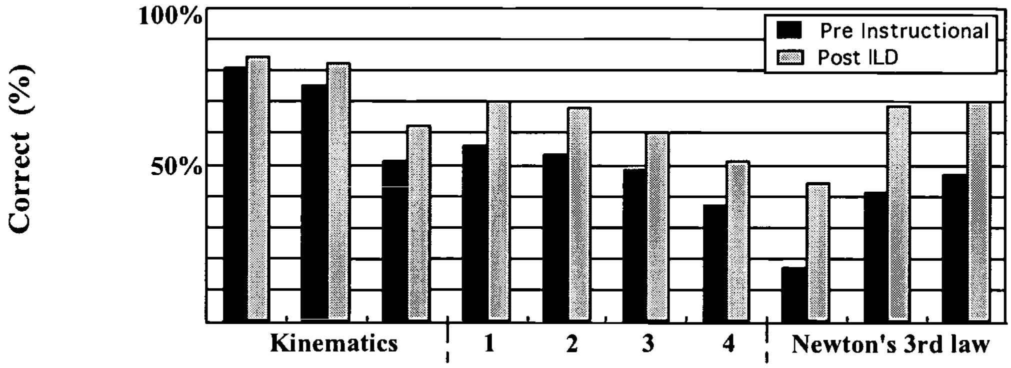


**Figure 2**. Showing the percentage of correct responses to questions in ten groupings, (including the four groups represented in Figure 1) as found in the 1999 experiment. Results are (1) responses from students in the experimental classes **before** instruction, and (2) responses from the same class **after** instruction using ILDs.

The first point to be noted is that Australian students are clearly very well prepared when they enter university. The on-entry scores are comparable with, or better than, the very best US institutions. In these times when high school teachers are being criticized, this finding deserves to be better known.

The second point, however, is less palatable. It is immediately obvious that the same gains in understanding, as were reported in the literature, did *not* occur. There was some gain, but the absolute values for the fraction of students answering the questions correctly fell far short of those in Figure 1. And the *relative gain* — the proportion of students who were unable to answer the questions before instruction, who were able to answer them after instruction — was even worse, considering that the Australian students had so much better scores on entry.

The teaching effectiveness of the ILD method, *compared with the control classes*, is shown in Figure 3, in which the *relative gain* for both groups of students is shown.

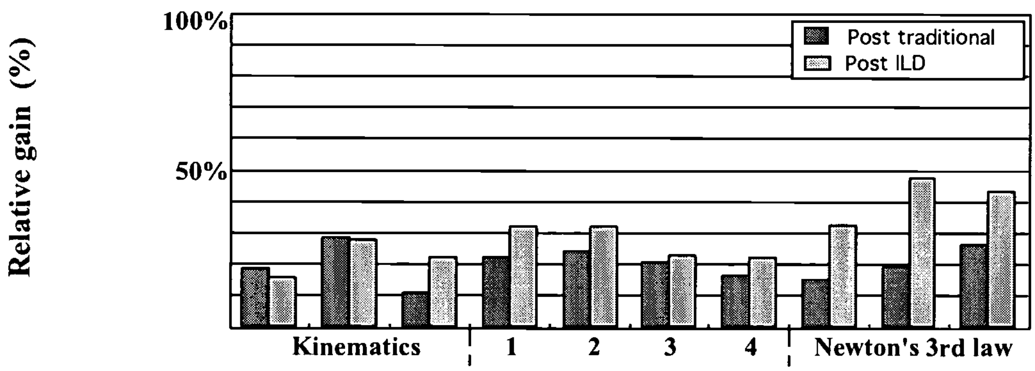


**Figure 3**. Showing the relative gain, as determined by post- and pre-testing (results expressed as a percentage) as a result of instruction in 1999 for (1) students in the control class, taught by traditional methods, and (2) students in the current experimental class, taught using ILDs.

On the basis of this data, a case can be made that the new teaching technique is more effective than traditional methods, at least so far as student understanding (as measured by the MPCE test) is concerned. The conclusion would seem to be that this new method of teaching, while effective in itself, does not yield the very impressive results claimed for it. There are of course many possible explanations for this: the teacher (IJ) may not have done things properly; the students may have been atypical; and/or the testing protocols may not have been careful enough. To answer some of these, the experiment was repeated in 2000, exactly as in the previous year.

## Results from the second attempt

Again there was one experimental class (of some 120 students) and two control classes, totalling about 300. All other logistical details were unchanged. However more attention was given to controlling what actually happened in the classroom. The teacher's performance had been videotaped in 1999, and inspection of those tapes suggested that, while he had done everything that was prescribed, balance between the different parts of the lecture were not ideal. To put it bluntly, he talked too much. For the second trial it was decided he should stick to saying only what was necessary and spend more time getting the students to interact more and to write more. It should be remarked that most lecturers rather like to hear themselves talk, and this constraint can be somewhat burdensome.

The results of the second trial are presented in Figures 4 and 5, which should be compared with Figures 2 and 3. (Note that responses to the last question on the previous graphs were not included in the 2000 results, for reasons that are not important).

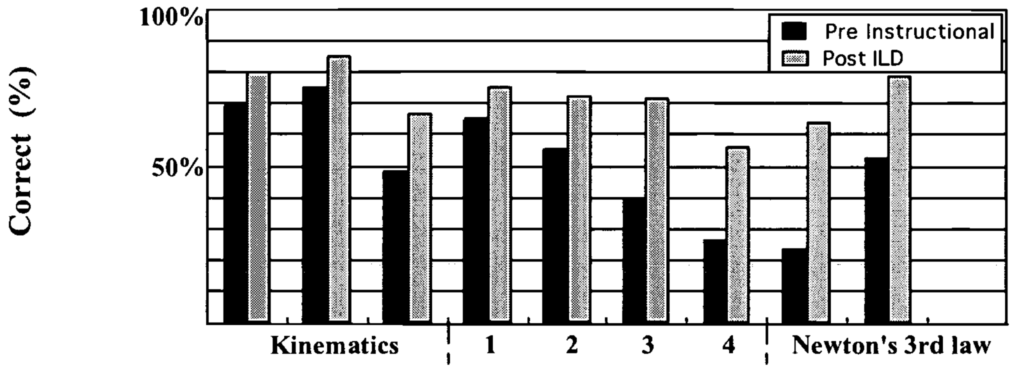


**Figure 4**. Showing the percentage of correct responses to questions in ten groupings, (including the four groups represented in Figure 1) as found in the 2000 experiment. Results are (1) responses from students in the experimental classes **before** instruction, and (2) responses from the same class **after** instruction using ILDs.

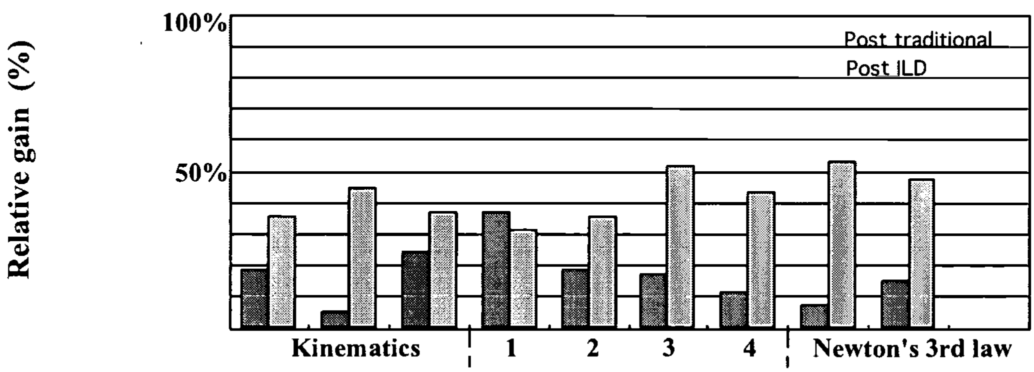


**Figure 5**. Showing the relative gain, as determined by post- and pre-testing (results expressed as a percentage) as a result of instruction in 2000 for (1) students in the control class, taught by traditional methods, and (2) students in the current experimental class, taught using ILDs.

It is immediately clear that the performance of the students in the experimental class had improved very markedly, while that of the students of the control class was similar to the previous year. Although the percentage gains are not as great as those in Figure 1, it is clear from the "raw" scores in Figure 4, that a very large fraction of the class seemed to understand the material — in the sense that, of all the students that can get to first base, that is who can answer the early questions on elementary kinematics, most of them could answer most of the rest of the questions.

That raises the very interesting question about those who *couldn't* answer the kinematics questions. Inspection of the original scripts show that these students got essentially *none* of the questions right (or at least about the same number they could have got by pure guessing). Yet all of the students in the class had passed physics at high school. It is almost as though this group had reached some kind of personal limit in their ability to understand the subject. This group needs to be studied very carefully in subsequent research.

## Conclusions

Clearly this experiment needs to be repeated, with different teachers and with different classes of students. Nevertheless it seems possible to conclude that this teaching method does yield results similar to those claimed for it. There is a note of caution to be sounded however. The unstated hope driving the experiment in the first place was that the ILD method might have been a teaching technique that could in some sense *guarantee* student learning, given only reasonable teachers and teaching administration. The previously published results seemed to suggest that that might have been the case. The fact that only modest gains were recorded on the first attempt in this case, when it was used by a very experienced teacher, suggests that there is no real guarantee.

Nevertheless, if this method is indeed a "right" way to teach physics (there may be others of course), very thorny questions suggest themselves, about the freedom of teachers to teach as they believe best. This paper would not dare address such questions.

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# A Flexible Learning Approach to Numerical Skills

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## Introduction

A recent development at Coventry University has been the introduction of Numerical Know-How, a module open to any student in the University who wishes to improve his or her numerical skills. The module is taken by students as one of the free choice modules in the first year of their programme of study. To meet the requirement of being accessible to every student it was decided that the module should be resource-based rather than lecture-based. Indeed there are no timetabled classes for the module. This avoids clashes with other modules which would deny some students access to this module.

This paper describes the resources available for students studying this module, the mode of operation and the students' reaction to the module. A variety of resources are used including paper, video and electronic. The electronic resources were originally made available over a local area network but in 99/00 were transferred to the Internet. This option was made particularly attractive following Coventry University's decision to adopt *WebCT* as a standard. In 99/00 all the University's modules had a *WebCT* site which students could easily access through a locally developed front-end, called *Learn On-line*. Whilst many of the University's modules made little or no use of their *WebCT* site, the site for Numerical Know-How became integral to the running of the module.

## Resources

The module consists of 12 units divided into three blocks of four. A simple video has been made to introduce each of these units. The videos, which were made in the University using a VESOL facility, are essentially a commentary to a set of *PowerPoint* lecture slides. The *PowerPoint* files can be viewed or downloaded (and printed) from the *WebCT* site. Paper copies of the slides are available in the University's Mathematics Support Centre.

Some of the slides on the video contain exercises for students to work through (answers and explanations are also given on the video). However, the nature of the material being covered is such that students need to practise repeatedly the skills being covered. To give students the opportunity to gain this practice and to receive feedback on their progress, a large question bank was created using the

*WebCT* assessment engine. Using this question bank twelve on-line tutorial sheets (quizzes) were created (one for each unit). The questions which make up a specific tutorial sheet are randomly selected from a pre-defined set. This allows students to take the same tutorial sheet repeatedly with little likelihood of being asked the same question.

A tutorial sheet typically contains 20 questions and to provide a large enough question bank to ensure different questions on repeat attempts at least 10 (preferably more) alternatives for each question are required. The requirement to author at least 2400 questions might appear daunting. However, by appropriate use of the *WebCT* question type 'Calculated Question' the amount of work required to generate these questions is significantly reduced. Figure 1 shows one of the questions. Within this question the two weights are chosen at random by *WebCT*. Figure 2 shows the authoring screen for a question like this. Parameters {a} and {b} are written into the question and the answer is specified as a formula in terms of {a} and {b}. Suitable ranges for the parameter values must be defined before the random values can be selected.

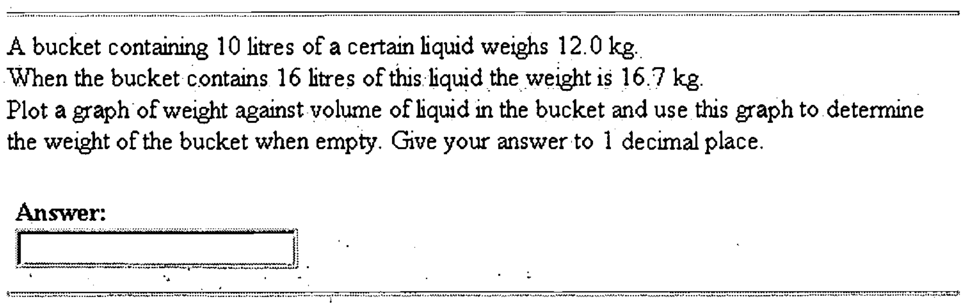


**Figure 1**. Sample question from *WebCT* question bank

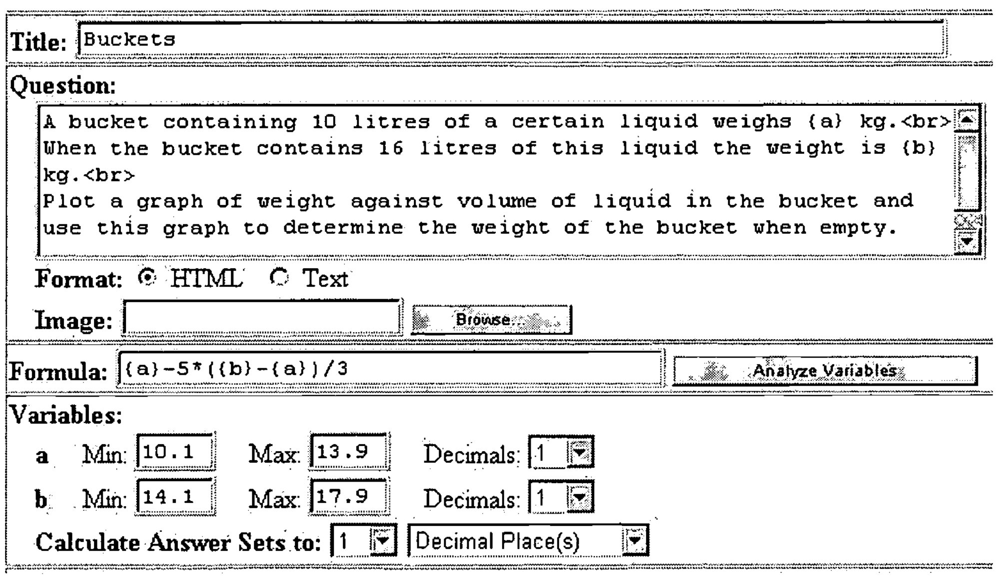


**Figure 2**. Calculated Question authoring in *WebCT*

There is a minor drawback with these questions in that the feedback for wrong answers can only be an outline of the correct process – the parameter values cannot be carried forward into the feedback to enable students to check specific interim values in their calculations. However, there are those who would argue that it is preferable to give an outline rather than a detailed solution as this encourages the students to think more fully through the information being presented and relate it to the specific values of their question rather than simply being spoon-fed the answer.

It was decided in the initial development of the module that the assessment should be an integral part of the learning process. To this end, students are encouraged to view all summative assessment as formative as well. To enable this to happen, students are allowed to take the three summative tests on-demand and also to have repeated attempts at the assessments. This allows students to use the tests formatively, as when they have completed a test they are immediately told not only their mark but also which questions were answered correctly and which incorrectly. This then indicates to them the areas that they most need to work on before they take the test again.

Whilst this may seem to be a generous assessment regime it appears to be particularly suitable to this kind of module which is essentially skills based. Furthermore, in order to pass, they have to achieve a mark of at least 75% on each of the three tests. At the start of the module the assessment is explained to the students by comparing it with the driving test. Just as in the driving test there is a known set of skills which the examiner is checking the potential driver has mastered, so in this module there is a clearly defined set of skills which a student must be able to demonstrate mastery of in order to pass the module. Also, just as in the driving test a minor error may not result in failure, so in this module the student is allowed the odd small slip.

Although there are no timetabled classes for this module there is still a human resource available to the students. The module leader can be contacted either by email or by using the bulletin board facility within the module's *WebCT* site. Those students wanting face to face contact are encouraged to use the University's Mathematics Support Centre, which is open as a drop-in help facility for 33 hours each week.

## Mode of operation

At the start of the year there is an initial meeting between the module leader and the students enrolled in the module. At this meeting the mode of operation of the module is explained and students are given a paper copy of the module guide (which is also available on the *WebCT* site). Essentially the students are told that the module is delivered by supported self-paced study. At this point the various resources available are described. During this meeting the students are taken to the University's Mathematics Support Centre and the fact that they can use it as much as they need is emphasised.

By the time the students attend this initial meeting they have been introduced to *WebCT* and the Coventry University front end *Learn On-line*. All students are given introductory sessions during induction week. Although it would be an exaggeration to say that, by the time of the initial meeting of Numerical Know-How, they are all comfortable with using the system, it is at least not totally new to them. Furthermore, the fact that it is used in a large number of modules means that this is not the only time they will see the system, although for most of them this will be the only module where all their assessment takes place in *WebCT*.

A further purpose of the initial meeting is that it enables the students to meet the module leader. For many students the next meeting will be when they take the first test. There is no requirement for a student to contact the module leader again until he/she wishes to have their first attempt at the first test.

## Student feedback

When students took the third and final test they were asked to complete a feedback questionnaire which explored their opinions of specific resources and of the overall operation of the module.

The first two questionnaires listed all the resources available for the module and asked students to state which they had used for more than two of the twelve units and also which they used the most. Figure 3 shows their response to the first of these questions. This shows that almost every student made use of the paper handouts, around two-thirds used the on-line quizzes (tutorial sheets) but the usage of the other resources was very low.

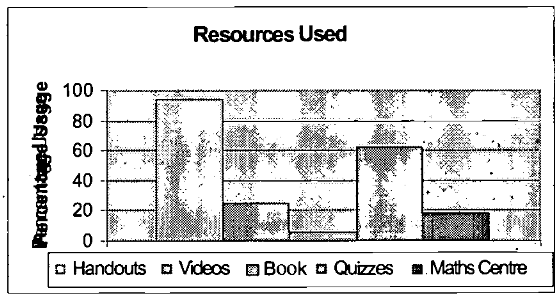


**Figure 3**. Percentage of students using the different resources

Not surprisingly given the answers to question 1, the paper handouts were identified as the best resource by 66% of students. The remaining 34% selected the on-line quizzes as the most useful.

When the module was in preparation the videos had been identified as a novel and, it was thought, appealing resource for the module. It became clear as the module progressed that the videos were not being used heavily. Further questions explored the amount of usage of the videos and reasons for the low usage. Figure 4 shows the breakdown of how many videos the students watched (the maximum possible was 12).

The three main reasons for the low usage are given in Table 1. There are important lessons to be learnt here. The first is that access to resources must be made as easy as possible. It was thought that the library was a good place to hold the videos as the students would, presumably, be regularly visiting the library for their other modules. There are facilities in the library for viewing the videos, they were not available for loan. The other two reasons for low usage are similar and could perhaps be summarised as the videos did not add significantly to what the students gained from the handouts. On the one hand this could be taken as evidence of the quality of the handouts, but it is more likely a reflection on the videos. The videos are essentially commentaries for the *PowerPoint* slides which make up the handouts. There is significant extra spoken explanation and active demonstrations of the steps required in the solution of some problems which only appear statically on the handouts. However the fact that the visual appearance of the videos was so similar to the handouts produced the perception that there was little difference between the two.

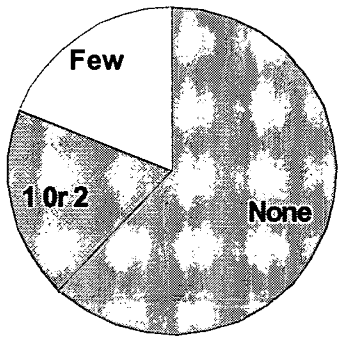


**Figure 4**. Number of videos watched

| Reason | % |
|---|---|
| Making time/inconvenience of going to library | 42 |
| Handouts were enough | 23 |
| Videos too similar to handouts | 19 |

**Table 1**. Reasons for not using videos

As can be seen in Figure 3, the on-line quizzes were used by almost two-thirds of the students. The only common explanation of infrequent use was that there were plenty of exercises on the handouts and so no others were needed.

The final question on the questionnaire asked students to write down the three best features and the three worst features about the module. A wide range of answers were given to this question although it is heartening that whilst almost all students listed three good things many listed less than three bad things. The most frequent best features were:

- multiple attempts at the tests;
- the self-paced nature of the module;
- the flexibility given by no lectures;
- the level of support;
- the availability of the resources on-line; and
- being able to take the assessments on demand.

Fewer bad features were listed and there was generally less agreement than with the good features. There were only two that were listed by more than one student. These were:

- the self-support nature of the module; and
- the lack of lectures.

Quite clearly it is impossible 'to please all of the people all of the time'. No lectures appears in both the best and worst features lists. The high level of support was praised by many but one student gave one of the worst features as 'Not having a lot of help'. One student said 'On-line assessment feels less formal' (this was a good thing) whilst another said that taking tests on paper was better than at a computer.

## Reflections

The basic operation of this module will remain unchanged for the next academic year. However, some lessons have been learnt about the practicalities of running a module like this. Initially the plan was for the module to be completely self-paced with no dates given for anything (other than a final date to meet the examination board schedules). This complete open-endedness was too much for many students. Not long into the module a number of them asked if dates could be set for the tests as this would give them 'something to work towards'. This request was complied with, although students who wanted to take the tests at other times were still permitted to do so.

Communication is a vital part of running a module like this. The student who wrote that one of the worst features was 'Not having a lot of help' was presumably not aware that there was up to 33 hours per week of help available in the Mathematics Support Centre, despite the fact that this was stated on the module guide. Either this was not read, or it was read at the wrong time (i.e. the beginning of the module), when the student did not feel in need of help and forgotten by the time help was required.

Email and the *WebCT* bulletin board were used to communicate with students. This may not have been totally effective, particularly at the start of the year when these were new forms of communication for some students. At the initial meeting more emphasis will be placed on the need to maintain communication with the module leader.

## Conclusion

Overall this method of delivering this module can be judged a success. Of the students who took all three tests only one did not pass the module. Some of the module resources, notably the videos, were not used as widely as anticipated but others were well-liked by the students. Although there were a few who did not appreciate this mode of delivery the overwhelming majority were satisfied. When asked to give the module a mark out of 5 (with 5 being the best mark) the average mark given was 4.

# Formative Assessment via the Web using ELEN

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## Abstract

A TLTP funded project called ELEN (Extended Learning Environment Network) seeks to provide both skills and subject based material on-line to supplement traditional teaching methods. This platform has been used to provide a short (5 question) multiple choice test that covers the material from each lecture in a series. The tests provide two levels of feedback and are not used in summative assessment in any way. In the first year some technical problems were encountered which reduced the number of students using the system. However, comments from those who did use the system have indicated that this method of providing formative assessment is useful and the method is currently being extended to other groups of students.

## Introduction

There has been considerable pressure in recent years to both increase student numbers and reduce the assessment load on both students and staff. These drivers may have good aims in themselves, but the combined effect has been to take the learning experience further away from Kolb's learning cycle. In particular, the opportunity to try out frameworks of understanding in a "safe" environment (i.e. one that does not contain an element of summative assessment) has been diminished, together with feedback. Our BSc in Environmental Science attracts large numbers of students (80-160) making individual monitoring and feedback difficult. In the first year, I teach solution chemistry and thermodynamics, with the summative assessment of this material being a 45-minute, 30 question, multiple choice test. Whilst there are two sessions embedded within the teaching programme that are devoted to problem solving, I felt that students had little chance to practice their own skills and understanding of the material. In addition, I was not convinced that the assessment method was entirely familiar to all of the students, as many of them are mature students. This could result in some students having anomalously low scores.

## Method

It was decided to offer students the chance to take short multiple choice tests during the semester. To allow easy access to the tests, the choice was made to provide them on-line. Plymouth is part of a consortium of universities that cooperate on a TLTP project called ELEN (Extended Learning Environment Network) based at the University of Lincolnshire and Humberside. This provides a "learning platform" via the Web that allows access to both skills and subject-based material. The system also records the results of tests to allow students to monitor their own progress and allows tutors to access information on the number of times a test has been run, etc. The ELEN platform was used to supply the tests.

Each lecture was supported by a short multiple choice test comprising of five questions. Each question had four possible answers. The screen presented to the students during a test is shown in Figure 1. Paging back and forth between the questions was allowed so that students could review and refine answers before finally committing themselves. At the end of the test, the score was displayed along with suitable overall feedback (see Figure 2). At this stage, individual questions could be revisited and along-side the question a piece of text explained why the selected answer was incorrect. However, this individual piece of feedback was carefully checked to ensure that it did not give away the correct answer (see Figure 3). After further study, the student could revisit the test to assess their improvement. Both the order of the questions and the possible answers were randomised to prevent students remembering answers by their position.

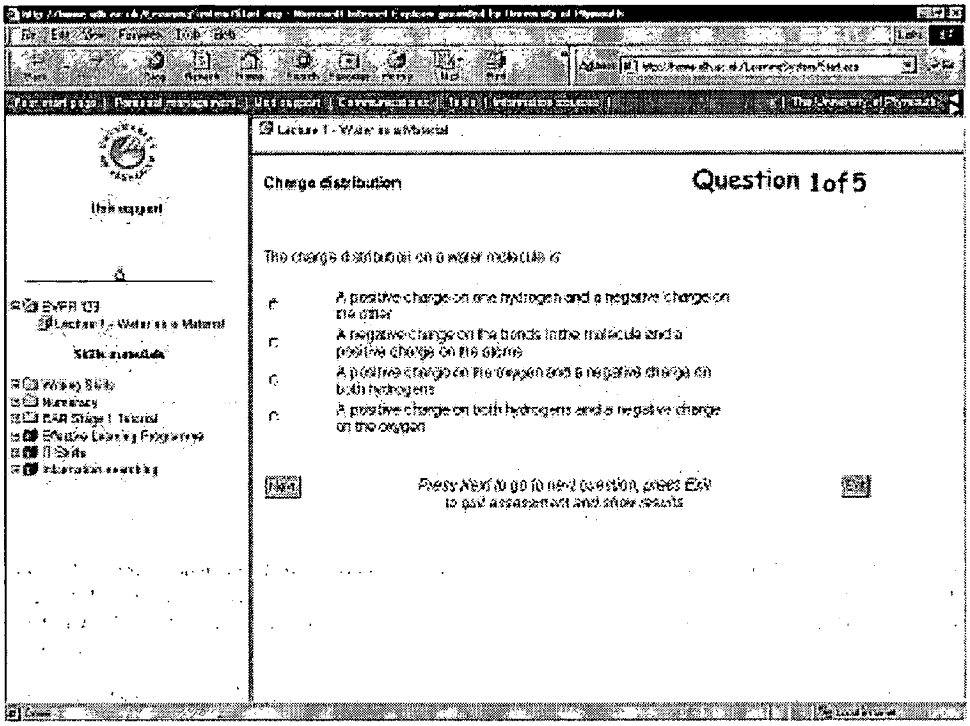


**Figure 1**. Question screen

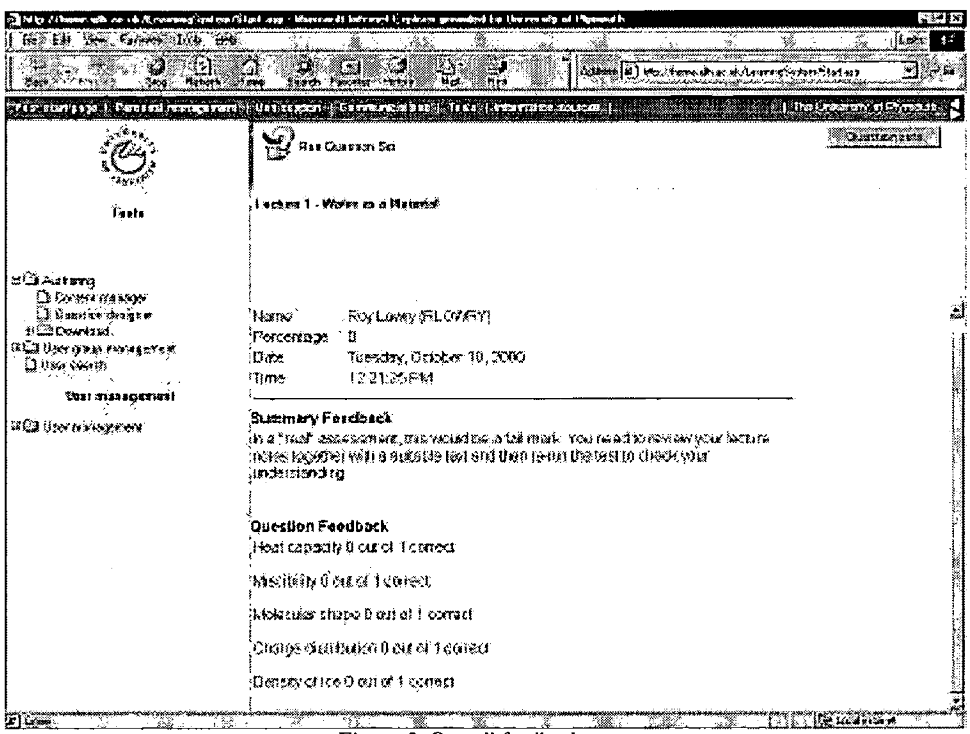


**Figure 2**. Overall feedback screen

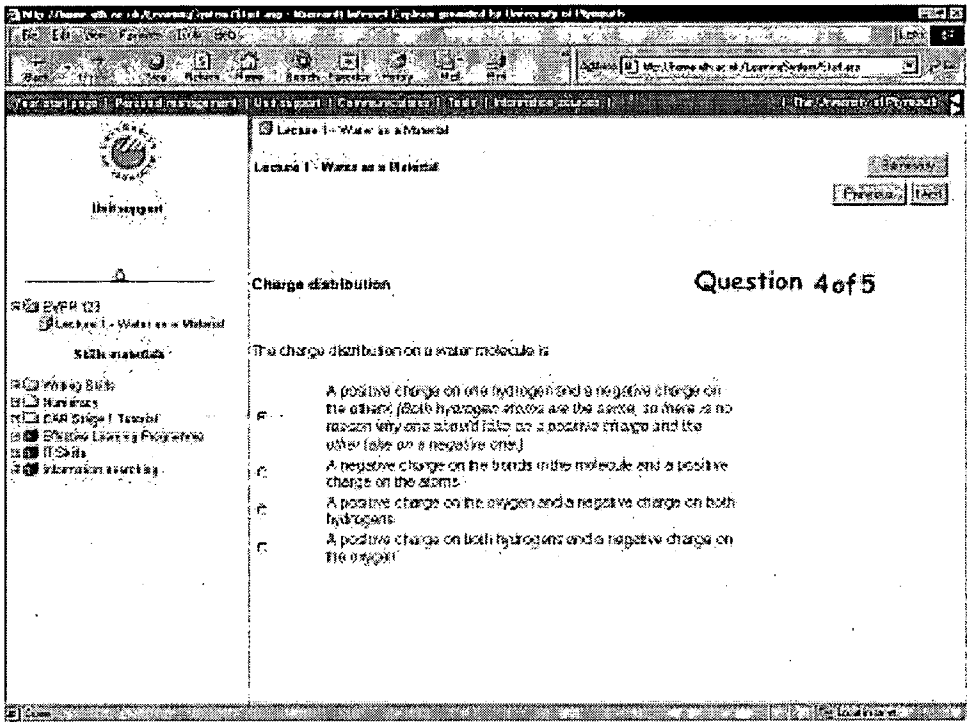


**Figure 3**. Individual question feedback

## Results

Unfortunately, the students did not use the system in large numbers. This was mainly due to problems registering students onto ELEN and it was therefore several weeks after the beginning of the lecture series before they could access the tests. This meant that:

- ☹ the link between lecture and test had been broken;
- ☹ the "habit" of checking understanding had not been established;
- ☹ formative assessments from other modules had begun and thus less urgent tasks were avoided by the students; and
- ☹ problems with the ELEN server and heavy web traffic occasionally restricted access or made the performance very slow.

It should be noted that all of these points are derived from the mechanism of delivering the tests rather than being due to the fundamental methodology.

However, the students who **did** use the system reported that the ELEN system:

- ☺ was a very useful learning aid;
- ☺ enabled students to more effectively target their study time to those areas that needed attention; and
- ☺ boosted confidence.

On the basis of this feedback from the students, the project is to continue and expand in this coming academic year (2000-2001).

## The future

It would appear that this method of allowing students to test their understanding is valuable and suitable for material where the summative assessment method is very similar. In the coming year, the system will again be available and we hope that the problems with students registering with ELEN have been solved.

In addition, funding for a similar project has been secured that will be used to create a bank of tests for our foundation year students based on a local (intranet) server using *Q-Mark Perception*. The two systems will be compared and evaluated.

## Further information on ELEN

Information on ELEN is available to non-consortium members via http://www.ulh.ac.uk/elen/

# Science at the Amusement Park

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What is up? What is down? What is a straight line? With beating heart we face the unusual movements.

An amusement park is a large hands-on physics laboratory, full of rotating coordinate systems, free-falling bodies and vector additions. It gives ample opportunity to experience Newton's laws with eyes, hands and body. The amusement park Liseberg in Göteborg is the largest amusement park of Scandinavia. It has long physics traditions – Albert Einstein gave a talk at Liseberg in 1923! Liseberg has many rides well suited for physics investigations, using simple equipment, as well as electronic accelerometers. Some investigations can easily be adapted to the local playground.

The heartbeat responds in different ways, both to the various accelerations and rotations of the body, but also to the thrill when in the queue. It can be monitored with electrodes on the body and the signal sent down to ground to be viewed in real-time by the classmates.

## "Slänggungan" – carousel with swings

A good starting point is the carousel with swings shown in Figure 1. As the carousel rotates, the swings hang out from the vertical line, thereby enabling the chains to provide the force giving the required centripetal acceleration, while still counteracting the force of gravity. Take a moment to consider which swings will hang out the most: the empty ones or the ones loaded with a child or with a heavy adult! In this situation students often pick the most heavily loaded swings. They watch in amazement as the carousel starts – all swings (at the same radius) hang at the same angle, independent of load.

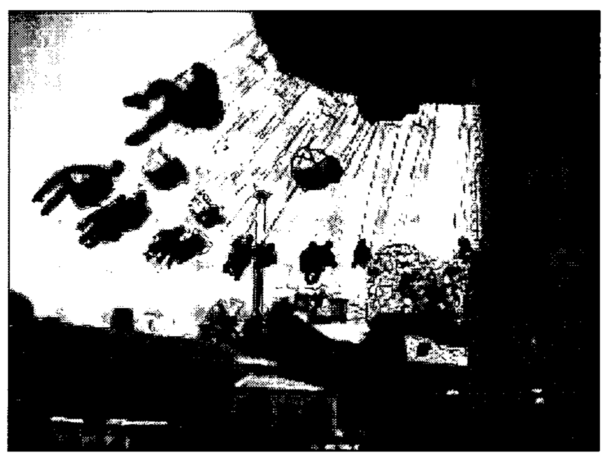

**Figure 1**. Which swings hang out the most as the carousel rotates? The empty ones or the heavily loaded ones?

This is an eye-catching example of the equivalence principle: the angle is determined by the ratio between the centripetal force and the weight. Since the intertial mass (entering the centripetal force) and the gravitational mass (entering the weight, mg), are equal, the angle is independent of the mass. Eötvös used the rotating earth as a giant merry-go-round by letting weights of different material balance from a rod suspended as a torsion balance. Refined Eötvös experiments are still performed, e.g. at the Eöt-Wash group at the University of Washington, giving lower and lower limits for possible deviations from the equivalence principle.[1]

### *Some exercises for the reader*

- Estimate the acceleration by looking at the picture.
- What is the apparent weight of a person on the ride?
- Estimate the rotation time, using the information that the chains are 4.3 m.

## Free fall

"Two seconds of weightlessness – can that solve the dieting problems for the summer", suggested the advertising when the "Space Shot" was introduced at Liseberg. Is it possible to be weightless in spite of temptations from candy floss or waffles with cream? What does weightlessness mean? Are astronauts weightless because they are so far from the gravitational field of the earth, as most new students suggest. (Try asking your group! Follow up by asking them to make a mental picture of the earth, the moon and the space shuttle. You could then ask them if and where there is a point where the gravitational attraction from the moon cancels that of the earth.) Or maybe they insist that weightlessness never occurs, since we cannot escape gravity? Most would, however, agree that an astronaut experiences weightlessness if the meatball on a fork hovers in front of the mouth. Meatball, astronaut and spaceship all fall towards earth with the same acceleration due to gravity. Similarly, an astronaut outside the space shuttle does not notice the effect of gravity, since he falls to earth with exactly the same acceleration as the orbiting space shuttle.

Many amusement parks now offer visitors the possibility to experience "two seconds of weightlessness". One example is the Space Shot, ("Uppskjutet") at Liseberg. After a quick tour up, the seats are decelerated to a stop before starting the free fall. Following the fall it lands softly on pressurized air. (The Free Fall e.g. at Gröna Lund in Stockholm, is instead decelerated by eddy currents produced by strong magnets.) The experience of weightlessness can be enhanced by taking along a small mug of water (1 cm of water is quite enough) and watch the water falling (don't pick a seat with headwind!). In the right conditions, the water seems to move slowly upward. Try it!

Often, the accelerations in an amusement park instead cause the rider to be significantly heavier than usual. "The Space Shot's emphasis is on the sudden blast upward from the bottom."[2] Figure 2 shows accelerometer data for the Space Shot, obtained with a "calculator based laboratory" (CBL) connected to a graphical calculator. The data can also be used to estimate the velocity at various points of the ride, and even the position. It is a good exercise in numerical sensitivity; the resolution of the accelerometer is about 0.013 g. What is the resulting uncertainty in the position after the ride (where, of course, we know that the rider is safely back to the starting point)?

A more visual accelerometer is provided by a slinky. Figure 3 shows three slinkys, one unloaded, one stretched by external forces, and one hanging free. Note how the spacing of the turns of the hanging slinky increases with the increasing load from the lower turns.

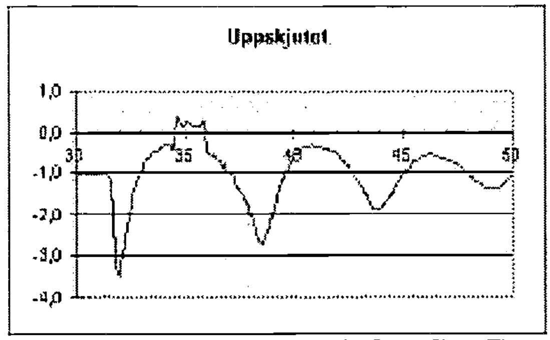


**Figure 2**. Accelerometer data for the Space Shot. The vertical axis is chosen so that standing on the ground gives "-1 g". From the figure we see that the rider experiences about 3.5 g for a short moment at the start and after 1.5 s of approximate weightlessness experiences 2.5 g, then 2.0 g etc. during the bouncing off the pressurised air.

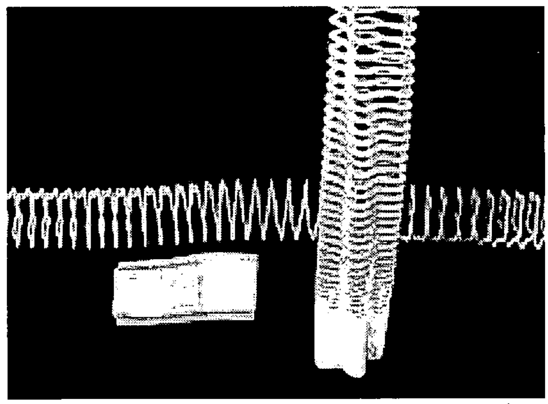

**Figure 3**. A "visual accelerometer": compare the spacing between the unloaded, the stretched and the free-hanging slinky. How will the spacing be affected by acceleration?

### *A few exercises for the reader*

- What do you expect the slinky to look like at the top?
- How long would the slinky be with half the number of coils (more suitable to take along on a ride!)?
- How do you expect a (half) slinky to look at the start of the Space Shot?

There are several versions of eye-catching towers in different parks. For example, the "Turbo Drop"[2] (available e.g. at Liseberg where it takes the rider 100 m above sea level – how far away is the horizon?) lets the rider fall with 2 g, causing an apparent "upward fall" of the water (don't hold the mug under your chin!). The "Free Fall" at Gröna Lund in Stockholm, on the other hand, really is a free fall following a long wait at the top. Thus, the water should be expected to remain in the mug, but it doesn't. Biology catches up with the physics in the form of a "Moro Reflex", familiar to parents of small children: a baby under sudden moves attempts to cling on to the mother, to avoid falling. Similarly, the rider feeling the seat drop, for an instant raises the hand, giving the water a small push upwards.[3]

## With the heart upside down

In an amusement park, the body is exposed to a large variety of unusual movements. How does it respond? One obvious measure is the pulse. For attractions, like the Space Shot, where the largest accelerations happen within time scales of seconds or shorter, the resolution of the heartbeat is somewhat low. The slow pendulum shown in Figure 4 is ideal for studying the reactions of the heart. Figure 5 shows accelerometer data from the ride (with the accelerometer pointing straight down to the seat throughout the ride). As seen from the data, the swing goes from one side to the other in about 10 seconds, until it finally makes it slowly over the top and completes a few full turns. The baroreceptors in the body sense the higher pressure in the head. Standing on the ground, the observer can watch the heartbeat dropping significantly about 2 seconds after the rider passed the top. One example is shown in Figure 6. (Note: not all rides are identical and the accelerometer data in Figure 5 were not recorded at the same time as the heartbeat in Figure 6.)

**Figure 4**. A giant pendulum with a counter weight. Additional energy is provided every time the pendulum passes the lowest point until it makes a full turn with riders hanging upside down.

### *Exercises for the reader*

- Using the accelerometer data, estimate the maximum angle at every turn.
- How does the period depend on the amplitude?
- The distance from the centre is about 12 m. What would be the period of a mathematical pendulum of this length? What would be the length of a mathematical pendulum with the period of this attraction?

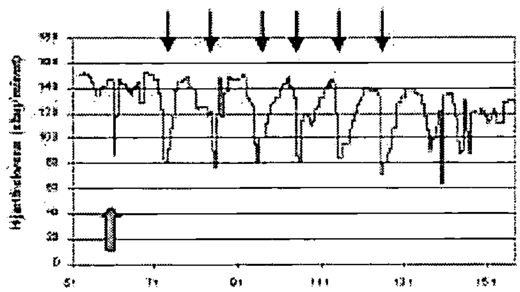

**Figure 5**. Accelerometer data from the ride

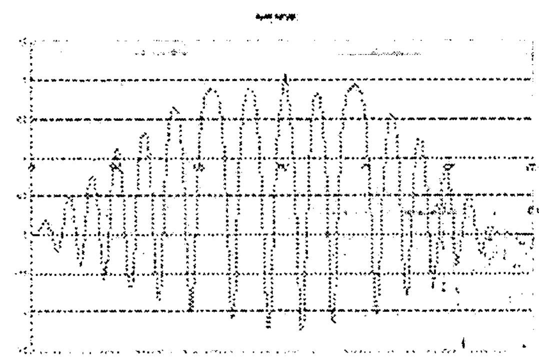

**Figure 6**. Example of heartbeat variations during the "Aerovarvet" ride

## The roller coaster

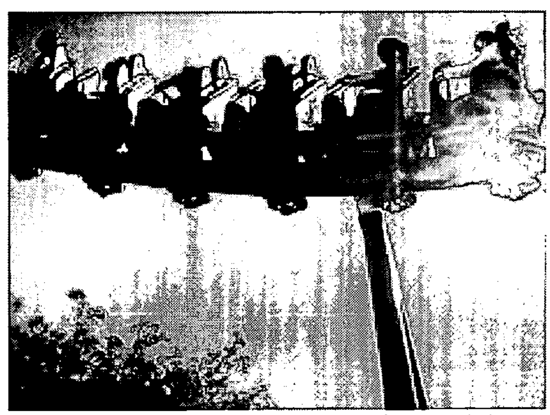

**Figure 7**. The roller coaster: How much energy is lost during the ride? What forces do the riders experience?

If you visit Liseberg, you must not miss the "Lisebergbanan". The train is first pulled up to 65 m over sea level, giving a good view over the city of Göteborg and over the building site for the new Science Center "Universeum", to be inaugurated in June 2001. The train takes you on a 2.7 km and 2.5 minute ride, to a large extent using the natural hills in the park, to a lowest point of 20 m and a maximum speed of 95 km/h. A roller coaster is a prime example of the energy principle, where the potential energy provided as you pass the highest point is all you have to take you round the track. How well is the energy conserved? A visual indication is provided by the nearby "Hangover", where the train makes a return trip on the same track. Before starting on the return journey, the train reaches *nearly* its original height, before being pulled the last few metres to the top.

A roller coaster also provides good examples of vector addition, as the train slopes and curves in different directions. In several places the tracks are built to imitate the free fall parabola.

The acceleration can be measured in several different ways. A "horizontal accelerometer" is provided by a little mass on a string, e.g. a Liseberg rabbit from one of the shops. It will bounce considerably, and needs to be stopped now and then, e.g. passing over the top of a hill. Watch the angle the rabbit makes to the track! (Remember, you and the rabbit undergo the same acceleration, but the rabbit hanging from the string does not feel the "normal force" from the seat.) The slinky can again be taken along as a vertical accelerometer, or more precise data can be recorded using electronic devices.

### *Exercises for the reader*

- Neglecting friction, what speed would you expect from 45 m height difference?
- At every instant all parts of the train have the same speed. Nevertheless, the ride in the front, back and middle are different. Why? In which seat will you feel the lightest? The heaviest?
- How do you expect the "rabbit-on-a-string" to hang as the train accelerates down a hill? As it turns to the left?
- Is the reading from a vertical accelerometer sufficient to provide information about "g-forces"?

## Before leaving the park

Visit one of the shops and get a helium balloon (take the smallest you can find) for experiments during the trip home. It works best in the large space provided in a bus, but works reasonably well also in a car. What happens to the balloon as the vehicle starts? As it turns? As it brakes in front of a traffic light?

## Using an amusement park in courses

Liseberg has been used in the introductory physics course for students in the educational programme "Problem Solving in Natural Sciences" at Göteborg University since its start in 1995. The Liseberg visit takes place within their first month at the University. Each of the 5-6 groups of about 6 students is assigned 3 different attractions of different types, with the task to describe the motion, figure out e.g. how energy is provided and, where applicable, the point where the rider would feel the heaviest and the lightest (how heavy? how light?) In some cases detailed data was made available by the amusement park. If a force is worked out with the wrong sign it becomes immediately obvious when confronted with the experience of the body. The observations and results from each group are then presented and discussed with the rest of the class in a session of about three hours, usually very enjoyable.

After the first year, more systematic instructions and information were presented on the Web, with help enlisted from a few students in a summer project, paid by the science faculty at Göteborg University. The pages have since been revised and extended, in view of experiences gained from working with the material in subsequent courses, and, of course, as new attractions have been added to the park. These pages, available at http://www.matnat.gu.se/slagkraft/, are now used by many schools from various parts of Sweden in their preparation for excursions to Liseberg. During the year 2000, the "FRN" provided support to enable graduate students to direct visits for school classes – and giving all of us easier access to children's thoughts.

During a visit to an amusement park the equations come alive. Second derivatives are felt throughout the body. The block on the inclined plane is replaced by a train in the slope of a roller coaster and "Gedanken experiments" from the textbooks can be realised in one of the most attractive hands-on laboratories available.

## Acknowledgements

Liseberg kindly let us use the "Aerovarvet" attraction, and also provided ride tickets for the pupils' experiments with water mugs, rabbits on strings or electronic measuring equipment. The funds provided by FRN were supplemented by contributions from the "strategic funds" of the science faculty, where the project was developed in a group including also Margareta Wallin-Pettersson, Elisabeth Strömberg, Jordi Altimiras, Marie Delin Oscarsson and the students Susanne Svensson, Anna Holmberg, Sara Bagge, Manda Gustavsson, Åsa Haglund and Sara Mattson. Further, we would like to express our appreciation of the loan of equipment from Texas Instruments and Zenit läromedel, and assistance from Bengt Åhlander and Jan-Erik Woldmar with the programs for the calculator. Richard Pendrill took the Aerovarvet and the roller coaster pictures.

## References

[1]The Eot-Wash group at University of Washington: http://mist.npl.washington.edu:80/eotwash/

[2]http://www.s-spower.com/, Manufacturer Information about the "Space Shot" and the "Turbo Drop"

[3]See the presentation of experiments at Gröna Lund at http://www.physto.se/gronalund/

# CALFEM as a Tool for Teaching University Mechanics

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## Abstract

Classical mechanics benefits greatly from the ability to demonstrate many concepts experimentally. However, modern mechanics relies more and more on new analysis methods such as the finite element method. In the teaching of mechanics these methods should be introduced, but the desire to experiment and build should be retained as a core issue.

One tool for tackling this topic is given by CALFEM[1]. CALFEM is an acronym for Computer Aided Learning of the Finite Element Method. It is a tool developed for teaching the finite element method but it is also used in research as well as engineering design.

The aim of CALFEM has been to provide a transparent link, such that the student can fully appreciate the intimate relationship between the mathematical models of a phenomenon, the finite element method and its computer implementation. This knowledge is not obtained by operation of commercial finite element programs. The pedagogical aspect of CALFEM has been part of the design from the beginning. In research, CALFEM has proven to be an efficient link between ideas and implemented solutions.

CALFEM runs as a toolbox to *MATLAB*[2] and provides all of the necessary tools for finite element calculations. The program has been carefully documented in an extensive manual that consists of a reference and a user's manual. The introduction and usage of CALFEM are strengthened by the close connection to teaching materials such as textbooks and exercises. The effectiveness of the system relies upon the widespread use of *MATLAB* at Lund University. The implementation of a web-based CALFEM has increased the availability of the package and allows for feedback and distribution of updates and additional material.

## Background

Due to the rapid development of computers numerical solutions have made it possible to use complex theoretical models. However, application of numerical methods increases the size and complexity of problems as a whole but as a result a more formal structure in the solution methodology has developed. The finite element method, used today by almost all engineering companies in the field of applied mechanics, is in itself a pedagogical method. The method allows the problem to be broken into simple parts, for which geometry, physical behaviour and boundary conditions can easily be described. The different matrices used in the method all have clear physical interpretations (stiffness matrix, load vector, displacement vector, etc.). Analogies between different physical applications can easily be made visible thanks to the formalism of the finite element method.

Still, teaching and using the finite element method in courses is a challenging task. The inherent dualism of the method requires a balance between the mathematical theory, physical understanding and the possibility to solve different engineering problems. The finite element method is a theoretical method which, however, can only be applied using a computer.

In ordinary textbooks usually there is only space for exercises treating theoretical issues and simple sample problems, which do not motivate the student to fully appreciate the intimate relationship between the theoretical issues in the finite element method and its computer implementation. Letting the students operate some of the many commercial finite element programs does not solve this fundamental problem. These programs are specifically designed for solving a variety of problems in an efficient manner and, in principle, a person may provide input data to such a program without any knowledge of the finite element method itself or even the physics behind the problem.

In any course on the finite element method exercises play an important role. In teaching or using the finite element method it is difficult to formulate meaningful exercises which address a single subject due to the rather involved numerical manipulations.

From a pedagogical point of view, the logical consequence is to have an interactive program. Simple requirements of such a program are: the program should be written in such a manner that all the usual subroutines related to any finite element program are present; the student should be able to combine these ingredients properly so that a calculation is possible; and it must be designed in such a way that a minimum of programming skills are required. The tool should be such that separate topics can be addressed and manipulated, such as material models, stability behaviour, dynamic response, etc., without requiring a large programming effort.

The development of the concept to teach and use the finite element method, in accordance with the above described experiences, started at the Division of Structural Mechanics at Lund University. This resulted in the CALFEM program originally developed in the FORTRAN programming language. Since its introduction more that one thousand students, engineers and teachers have used the package. It has been redeveloped and transferred to a toolbox within *MATLAB*. This was done in collaboration with the Division of Solid Mechanics at Lund University.

We have found that CALFEM is also extremely useful as a research tool. In several graduate projects and dissertations CALFEM has been the environment where new finite elements, new mathematical models, new non-linear solution strategies have been created and tested, and where complicated structures have been modelled and their behaviour simulated.

## CALFEM as part of an educational idea

The educational idea is best highlighted by comparing it to the traditional way of teaching the finite element method.

> Traditional textbooks on the finite element method assume that the physics of the method is known or easily accessible to the reader.
>
> *whereas*
>
> In our teaching method the physical phenomenon is as important as the solution strategy, thus physical interpretation is continuously connected to mathematical and numerical treatment of the problem.

Finite element software in traditional teaching is handled in two separate ways. Either the students write their own programs in FORTRAN, C, etc. which is a time consuming task, or one of the many commercially available codes is used. When commercial codes are used some of the concept-based goals are lost since students can solve the problem without understanding the underlying physics and numerical methods. With CALFEM the students are required to build their own finite element code for every problem they solve, but in a much more time efficient way than traditional programming.

A fundamental goal of CALFEM is to use the above-described concept for teaching the finite element method. Through this approach, the students obtain a physical and numerical "language" thus in the future commercial finite element codes may be easily interpreted.

More importantly the students can see analogies between different physical applications. In fact, this is emphasized by using the same element for different physical applications where equivalent material properties are used. Thus broadening of the students' conceptual picture is encouraged, since different physical ideas can be grouped together and treated in a unified manner.

CALFEM is now used in different courses which take advantage of the fact that new ideas can easily be implemented and that existing routines can be enhanced. One such course deals with material modelling, where non-linear elasticity, plasticity, etc. are considered. The foundation obtained by using CALFEM is then used to study different material models as well as for writing non-linear finite element programs. The conclusion from this course is that CALFEM has fulfilled one of its tasks as the students obtain an understanding of the material modelling aspects and the numerical issues involved without getting confused about basic matters regarding the finite element method.

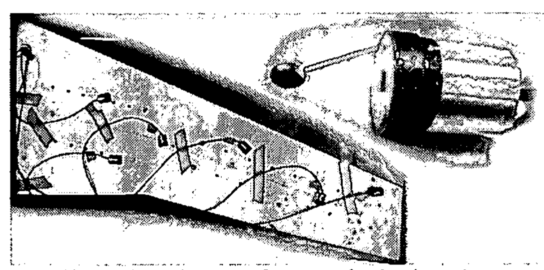

**Figure 1**. A close up of a swept-back wing where accelerometers are fastened. In the right corner an accelerometer is shown.

An example of problems treated in the structural dynamics course is shown above. An airplane wing including fuel reservoirs is analyzed with the aim of reducing vibrations. The students make measurements on the object and analyze the behaviour via computer simulations and propose changes so that certain constraints can be fulfilled, such as vibration reduction at a specific location. The solutions to these tasks usually have no unique answer. Different strategies may be applied in the solution for example how the masses representing the fuel tanks should be modelled.

The physics in the course is described in textbooks dealing with structural dynamics, modal analysis, many degrees of freedom system, transient analysis, etc. The literature describes phenomenological models in a mathematical language. However, these models are usually so complex that computer solutions are required, but in addition they must be related to the real world. These are the tasks that should be solved by using CALFEM.

CALFEM's goal is to strengthen the coupling between mechanics, the finite element method and 'the ability to solve real problems'. In CALFEM the student can copy a routine and modify it so that it fits a specific purpose such as modelling a mass that changes in a prescribed way. The application to a wing allows an integrated natural mix between theory, phenomena and numerical methods.

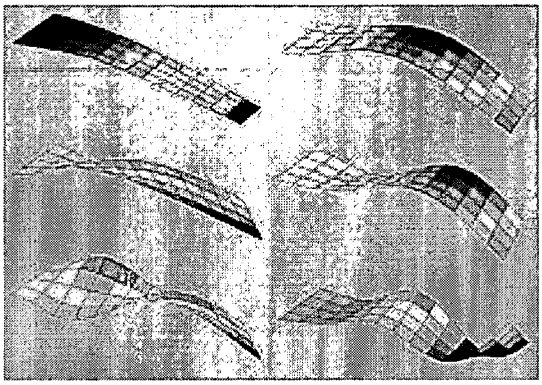

**Figure 2**. The result of one of these studies showing the six first eigenvalues

## Consequences for students

We strongly believe that the educational idea leads to:

- a deeper physical understanding between different physical applications;
- the students stimulated by being a part of the CALFEM development which reaches into research;
- the students stimulated by different physical ideas that can be modelled in a very simple manner; and
- the students stimulated by new ideas, and theoretical models can be built upon the existing knowledge obtained by using CALFEM.

## Illustrative examples

To illustrate the analogy between different physical applications, used in the teaching, some very simple examples will be considered. In addition, the purpose is to show the basic steps in a finite element calculation. The general steps in linear finite element calculations are:

- define the model;
- generate element matrices;
- assemble element matrices into the global system of equations;
- solve the global system of equations; and
- evaluate element forces in a structural problem.

### *Linear spring system*

Consider the system of three linear elastic springs, and the corresponding finite element model. The system is fixed at its ends and a single load F is applied.

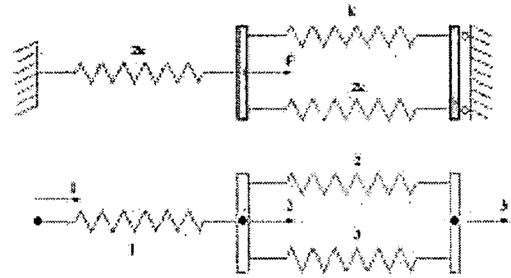

**Figure 3**.

The computation is initialized by defining the element connection (topology) matrix Edof,

```
>>Edof=[1 1 2
        2 2 3
        3 2 2];
```

where the first row is the element number, the second and third the global degree of freedom. The topology matrix defines how the model is built up. The global stiffness matrix K (3x3) of zeros,

```
>>K=zeros(3,3);
```

and load vector f (3x1) with the load F=100 at position 2

```
>>f=zeros(3,1); f(2)=100;
```

Element stiffness matrices are generated by the function spring1e. The element property ep for the springs contains the spring stiffness k and 2k, where k = 1500.

```
>>k=1500; ep1=k; ep2=2*k;
>>Ke1=spring1e(ep1);
>>Ke2=spring1e(ep2);
```

The element stiffness matrices are assembled into the global stiffness matrix K according to the topology matrix

```
>>K=assem(Edof(1,:),K,Ke2);
>>K=assem(Edof(2,:),K,Ke1);
>>K=assem(Edof(3,:),K,Ke2);
```

The global system of equations is solved considering the boundary conditions given in bc

```
>>bc=[1 0
      3 0];
>>a=solveq(K,f,bc)

a=       0
    0.0133
         0
```

Element forces can then be obtained by considering a single element, let say element 2. The displacement for this element is obtained as

```
>>ed2=extract(Edof(2,:),a)

ed2=   0.0133    0
```

where the first value corresponds to degree of freedom 2 and the second to 3, all according to Edof. The spring forces are evaluated as

```
>>Ef=spring1s(ep1,ed2)

Ef=   -20
```

### *One-dimensional heat flow*

A wall is built up of concrete and thermal insulation. The outdoor temperature is -17°C and the temperature inside is 20°C.

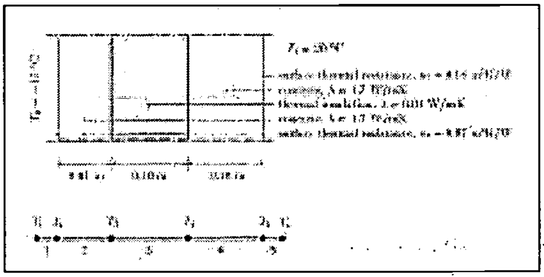

**Figure 4.**

The wall is subdivided into five elements and the one-dimensional spring (analogy) element spring1e is used. From the finite element formulations it turns out that an equivalent spring stiffness for thermal conductivity is $k = \lambda A/L$ and for thermal surface resistance $k = A/m$.

The program below emphasizes the analogy between the linear spring model and the one-dimensional heat problem

```
>>Edof=[1 1 2
        2 2 3
        3 3 4
        4 4 5
        5 5 6];

>>K=zeros(6);
>>f=zeros(6,1);

>>ep1=[ 1/0.07 ]; ep2=[ 1.7/0.07 ];
>>ep3=[ 0.040/0.10 ]; ep4=[ 1.7/0.10 ];
>>ep5=[ 1/0.18 ];

>>Ke1=spring1e(ep1); Ke2=spring1e(ep2);
>>Ke3=spring1e(ep3); Ke4=spring1e(ep4);
>>Ke5=spring1e(ep5);

>>K=assem(Edof(1,:),K,Ke1);
>>K=assem(Edof(2,:),K,Ke2);
>>K=assem(Edof(3,:),K,Ke3);
>>K=assem(Edof(4,:),K,Ke4);
>>K=assem(Edof(5,:),K,Ke5);

>>bc=[1 -17; 6 20];

>>T=solve(K,f,bc)

T = -17.0000
    -16.0912
    -15.5567
     16.8995
     17.6632
     20.0000
```

The heat flow is obtained in exactly the same way as the element forces were obtained in the linear spring model.

### *Plane structure*

The purpose of this final example is to show that complex geometries can be dealt with without sacrificing the structure and formalism of the method. The 5 mm thick plate with a hole is considered, the material is assumed to behave as an isotropically linearly elastic material, with Young's modulus $E = 210\text{MPa}$ and Poisson's ratio $v = 0.3$. The loading is a prescribed displacement.

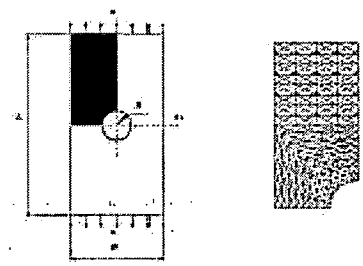

**Figure 5.**

Due to symmetry conditions only one quarter needs to be modelled. The right figure shows the finite element mesh used in the calculations. For simplicity the geometry and load as well as boundary conditions are loaded from a file.

```
>>load hole
```

The finite element program can then be written as:

```
>>E=210000; v=0.3; t=5;
>>ep=[1 t];

>>K=zeros(ndof,ndof);
>>f=zeros(ndof,1);

>>D=hooke(ep(1),E,v);
>>for i=1:nelm
>> Ke=plante(ex(i,:),ey(i,:),ep,D);
>> K=assem(edof(i,:),K,Ke);
>>end

>>a=solve(K,f,bc);

>>ed=extract(edof,a);
>>es=plants(ex,ey,ep,D,ed);
```

where the final lines calculate the stress distribution in the plate. In addition, for presentation of the results several commands are available.

## References

[1]CALFEM, http://www.byggmek.lth.se/Calfem/
[2]*MATLAB*, http://www.mathworks.com/

# Pollen Image Management: Using Digital Images to Teach Recognition Skills and Build Reference Collections

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## Introduction

A reference collection is a necessary outgrowth of many research projects, including some undergraduate PBL. The need for modern morphological information at appropriate taxonomic levels seems to drive the early stages of many projects. In palynology, the development of these collections is often a fundamental part of researcher training. It is a time consuming and materials-expensive task that includes: the gathering and identification of herbarium specimens; the destructive processing of the specimen; the storage of reference vials of material; and the recording of the images for later cross-referencing. The microscope slides and processed materials have a limited (undefined) shelf-life. Retrieving reference material for routine comparison with unknown materials can be frustratingly slow using reference microscope slides. Consequently, students have traditionally used a combination of annotated sketches and photographic print film to compile a reference collection. Most pollen laboratories are festooned with hardcopies of pollen images for the enjoyment of those in the laboratory and the collections tend to 'go with' the collector. This does not result in accumulation of taxonomic information.

The 'siliciophobic' response of teachers and researchers described by Attwood (2000) has an additional variety called 'pixilophobia'. Digital-image technology and the Web are now widely available and accepted in most applications except in the collection and sharing of reference materials. For example, the field of palynology has its professional heart in image recognition, yet the systematic collection and sharing of images over the Web or on CD-ROM is relatively recent. This paper seeks to promote this recent development. Although this paper relates to a pollen collection, however, the principles and techniques used have universal application to people working with image management. We believe the model described here is a useful development, and although the endpoint may be *LucID* (Norton et al. 2000), we hope this low-budget model encourages others in the sharing of reference materials in digital forms.

## Greater efficacy in image management

To achieve greater effectiveness we have developed a simple system that students can use to build high quality databases of reference and unknown materials with little training or specialised equipment. The system replaces the older retrieval problem with near instantaneous access to a notionally unlimited number of reference grains. The digital images are more readily shared with others and replace the hardcopies of pollen images.

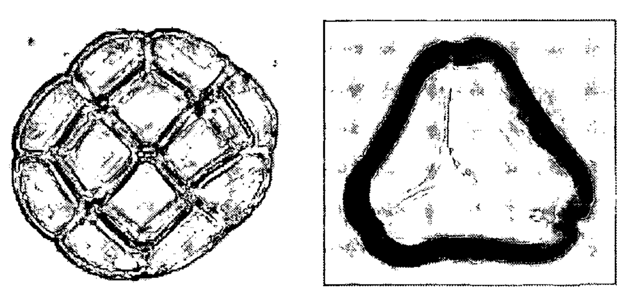

**Figure 1**. Examples of digital images, *Acacia terminalis* and *Eucalyptus gummifera*

The system uses digital images that replace: the delays between taking a photograph and having it added to the reference collection; the delay of duplication for sharing images with others; and the costs and delays of photographic procedures. Digital images also allow easy duplication without any loss of resolution. Training of undergraduate and research students is more efficient because images and unknown grains can be routinely compared on the screen. With a few minutes training, the same equipment can be used for 'capturing' images of unknown grains for later identification or comparison. Preliminary results with honours students suggests it reduces the microscope work time by approximately 50% and concentrates the time needed for experts to identify unknown grains.

## Why a digital collection from the Geomorphology and Quaternary Science Research Unit?

The Unit has a diversity of research sites and the combined pollen reference collections cover a range of biomes. These collections include material from Tasmania, the Hunter Valley (and other lower north coast sites), arid sites in the Northern Territory, Queensland, New South Wales and Western Australia. These collections traditionally consisted of separate site collections, managed by separate researchers with pollen samples on microscope slides and photographs stored in albums or glued to filing cards (Figure 2). Accessing these collections was unwieldy and time consuming. New researchers have often worked with limited or incomplete reference sets and this has slowed progress on analysis of the fossil materials.

**Figure 2**. A traditional format reference collection

In response to multi-user demands for reference materials, and falling costs per unit of computer processing and storage, we investigated top-of-the range image grabbing and processing configurations. The set-up costs of these systems on existing scopes were in excess of $ 20 000 and required specialised operators and software. During our recoil from this discovery we identified a 'diminishing return' in performance improvements beyond a few thousand dollars. In other words, to get small increases in performance we were expected to spend large amounts of money on a single unit.

With the impatient enthusiasm of postgraduate researchers driving the project, the occasional injection of small amounts of money and even an 'experiment' on a stolen Unix machine, the image grabbing capability was built onto two existing microscopes linked to a computer.

Our initial interest grew into a commitment to rapidly share images at no profit using both Web http://www.newcastle.edu.au/department/gg/pol/0intro.html and CD-ROM media. In 1998 we ran a workshop on image grabbing for pollen analysis and established there was some interest in this kind of tool. In 2000 we presented a paper on the pollen reference collection and the image grabbing system at the Southern Connections Congress at Lincoln University, New Zealand, 17–22 January 2000 and a poster and display at the Quaternary Studies Meeting at the Australian National University, Canberra, 7–9 February 2000. There have been requests for copies of the CD-ROM, offers of additional collections and information on how to set-up similar hardware and software systems. The step-by-step protocol for developing images for the collection are available from the authors who are also happy to discuss set-ups for new applications.

## The collection system

The collection is designed for use on standard PCs running software such as *Netscape Navigator* or *Internet Explorer*. The JPEG image file format was selected for small file size and compatibility across software. At the moment the collection contains about 450 taxa, with another 900 taxa in progress. The CD-ROM can hold images representing 2000 taxa.

The software is structured to use the brain's remarkable ability to recognise spatial pattern and make visual comparisons. Unlike conventional databases searches are image-driven rather than text driven, using selectable sketches and thumbnails to move through the collection and select best matches. The hierarchical complexity is minimised – researchers are never more than two mouse clicks from an image. The system is computer mouse-controlled and does not clutter the microscope workspace with a keyboard nor the researcher's mind with esoteric morphological terminology. There is a minimum of text and specialised jargon. This increases accessibility and reduces query-to-solution times. The new collection can be used in conjunction with the ANU collection (http://pollen.anu.edu.au/pollensearch.phtml) that is more text-based with images only available at the final stages of identification. We plan to develop a *LucID*-based key in future that will remove the hierarchical structure of identification.

Following the traditional dichotomous structures, the opening page provides 2 routes: a graphics interface page of 52 thumbnail-sized drawings; and a taxonomic treatment based on Family names. We have found the line drawings are the preferred route in most situations. Selecting one of the thumbnails opens a number of thumbnail images (approximately 4 Kb each) of pollen grains. Selecting one of those images opens a large format image (approximately 350 Kb) showing the name of the grain with a scale bar. Selecting 'Back' allows for quick comparisons with other morphologically similar grains.

The large format images for each taxa are composites of a few images taken using the Hi-Lo method to show surface textures and cross-sections and usually include polar and equatorial views. Morphological variations within a species can be reflected by relisting the images under a couple of thumbnails. For example, grains that are usually present as crushed grains can be represented by two line drawings, one showing the undamaged form and the other a crushed form. Saved with the image are a scale bar and the name of the taxon so the grain, scale and source are stored together. Some of the images have been scanned from 35mm print film photographs, but most are digitised directly from microscope video cameras. Digital "enhancements" that modify the appearance of the grains are not used to ensure images match what might appear during routine counting. The images can be enhanced from the originals if desired.

We have found it useful to develop a standard protocol for naming files to help in knowing exactly what an image is and how it was gathered. For example the file name "Solanum plicatile EV1L500.JPG" gives the following information: the specific epiphet, the equatorial orientation or type of view (EV), the image number (1), the depth of focal plane (low), and that the image was taken on the Leitz scope at 500x magnification. When a number of images were compiled together we added the scale, family and specific epiphet into the background (Figure 3). From the earlier example, the image was now simply "Solanum plicatile.jpg" these files are approximately 350 Kb. From these images we copied and resampled images to save them as thumbnails that are 125 pixels high. These thumbnail images were matched to the line drawings and from them allocated a group number. The thumbnail file name became "36Solanum plicatile.jpg". This protocol saved considerable time in building the Web pages.

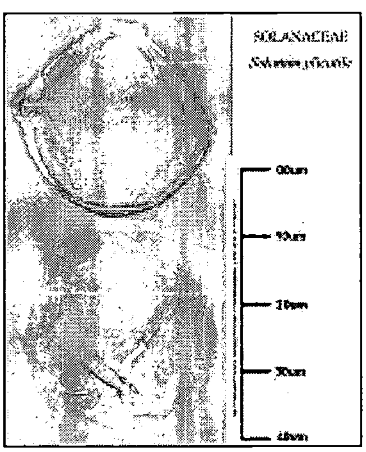

**Figure 3**. Example of a reference pollen grain

## Setting up the system yourself

The hardware configuration we have used is probably already antiquated, for example video cards are now frequently standard in contemporary computers. Nevertheless, the decisions we made in setting up the system should encourage researchers without large budgets. We used a colour CCD video camera purchased from *ISSCO* for $500. C-mount adaptors threatened to be an expensive part of the set-up. So C-mounts were made using 50mm PVC drain fittings and the correct tube lengths were set by having a sliding section. This fitting was done easily on a *Leica* scope but we needed a precision steel engineering company to produce a mount for the *Zeiss* Axioplot microscope.

The television we use for checking image quality prior to grabbing is 46 cm however we have also used a portable 32 cm. The television is useful for expert identification and checking image quality, although one postgraduate dreamed of counting pollen from video, we believe it is not suitable for counting. As an aside, the television set-up has been useful for teaching classes using both the light and dissecting microscopes.

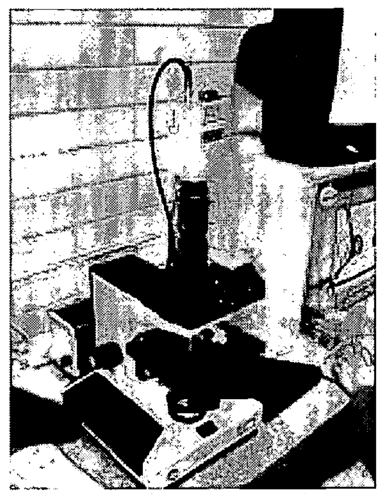

**Figure 4**. Detail of the image grabbing set-up

A plug-in to the serial port called *Snappy* converted the video signal to digital images. The short-lived 9 volt battery was replaced by a plugpack regulator and transformer from *Dick Smith*. The computer is a Pentium II loaded with the software *Photodelux* that is sufficient for capturing the image, editing and saving. For bulk editing, scanning prints and compiling composite images we have used *PhotoImpact* or *Corel Photo-Paint* Version 8. The baseline option to set-up a system is approximately $1000 and this cost is probably falling.

## Conclusion

We are planning to group images under the thumbnail leader by size and surface texture so researchers can use size or surface to speed their search. The development of Genus and Species search capabilities and provision of provenance and processing information for each image is a priority and will probably be done under the *LucID* system. We are also developing an instructional CD-ROM for demonstrating and teaching some aspects of Quaternary palynology.

The image grabbing and sharing project that started humbly has developed into a reasonable model for others who have large numbers of images that require some management. We have used cheap and readily available materials to achieve our goals. The equipment has, we feel, repaid the costs and trouble of set-up and we are keen to convert others to the digital image path. We hope this low-budget project encourages others to contribute collections, where pixel leaders are already present, or take up the challenge of using pixels to share reference materials with students and other researchers.

## Acknowledgements

This is a contribution of The University of Newcastle Geomorphology and Quaternary Science Research Unit. We acknowledge with thanks the contributions of Eric Colhoun, Mike Macphail, Mike Cvetanovski, David O'Brien, Richard Dear and Lucy Gayler. Thanks also for suggestions from John Dodson, Scott Mooney and Scott Anderson. The work would not be possible without the support of the Discipline of Geography and Environmental Science.

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Norton, G. A., Patterson, D. J. and Schneider, M. (2000) LucID: A multimedia educational tool for identification and diagnostics, *CAL-laborate*, UniServe Science, **4**, 19-22.

# UKESCC Earth Science Courseware Goes on the Web

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## Introduction

During the last six years, courseware developed by the UK Earth Science Courseware Consortium (UKESCC) has been distributed in application style format to institutions and individuals in over 40 different countries[4,5,7-9]. The last of the scheduled 21 Earth Science courseware modules was completed in 1999. Since that time, further development of the software has focused on providing easier access to the large amount of material available. This has been achieved by adding a front-page with entry points to all the modules, and by adding indexes.

The latest development, designed both to aid access and to help tutors integrate this resource into their teaching, has been the conversion of the original stand-alone application style version into a Web version.

This article outlines these recent developments, describes how the courseware content extends into subject areas beyond the confines of geology, and outlines the range of educational levels of its users.

## Indexes

Additions to the UKESCC courseware at the start of the year 2000 included a single front-page and indexes. Both features are designed primarily for use when all 21 modules are available and were introduced to allow easier access to specific pages of material, and to specific terms and topics.

The indexes are used in a similar way to a book index and enable users to quickly find and access specific topics. Two types of index are provided: subject indexes for individual modules; and a global index to all the modules. Both are accessible from all areas of the modules.

The subject indexes have been compiled from menu entries, page titles and by manually scanning all the material for terms, and topics not otherwise covered. The global index has been produced by merging subject index entries for all the modules, sorting them alphabetically, then storing them under separate letters of the alphabet.

The global index makes only minor reference to individual courseware modules and allows the courseware content to be accessed and used in a completely different way to that originally envisaged. Originally, it was anticipated that users would only wish to work steadily through the material in individual modules. While they can still do this, the global index provides the means to quickly find, then jump to, very specific terms and topics, often buried deep within individual modules. In this respect it makes the suite of modules appear like a giant geological encyclopaedia.

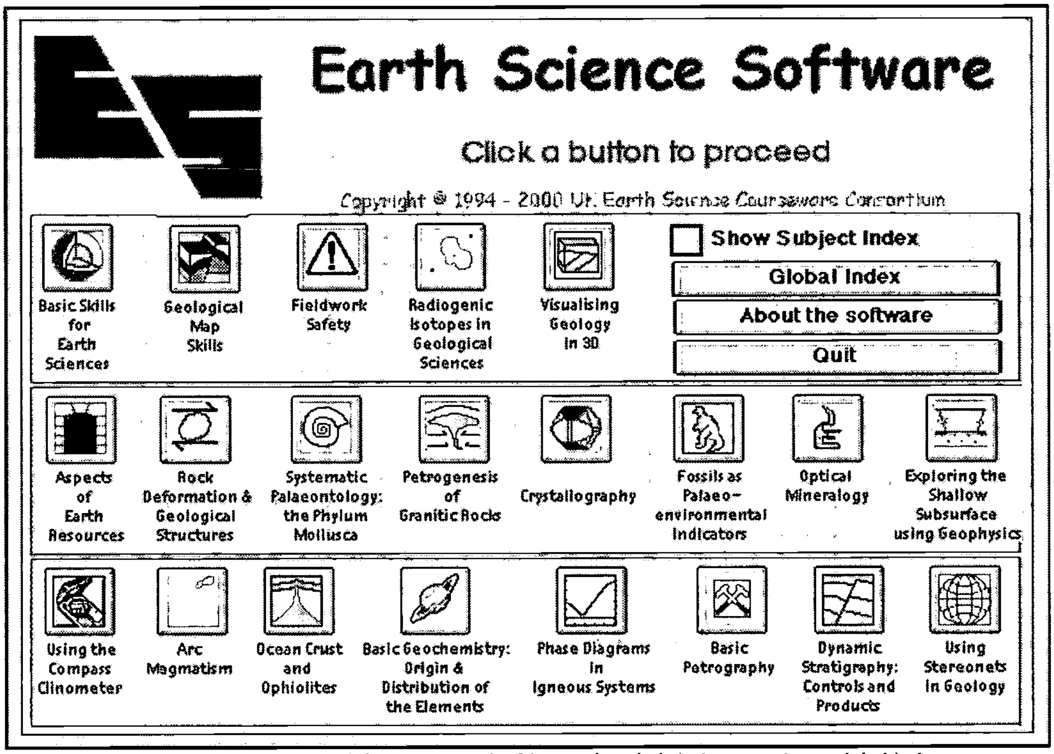


**Figure 1**. Front-page providing access to the 21 modules, their indexes, and to a global index

## Web version

The UKESCC courseware was developed using *Authorware*; an authoring software application ideally suited to the production of multimedia style CAL packages. Most of the UKESCC courseware was developed at the time when the Internet was in its infancy, and the only type of output from *Authorware* was a stand-alone application-style format. It is only comparatively recently that *Authorware* has been extended to generate output that will run over the Web, in addition to the stand-alone format.

A demonstration version of the courseware is available without restriction on the Web at http://www.man.ac.uk/~ukescc/demo.html. The complete version is available to licensed users, and can either be accessed from the UKESCC web server or mounted on a user's web server. All versions require the *Authorware* Web Player plug-in to be installed where it can be accessed by your browser. The plug-in is available free from the *Authorware* web site.

One reason for providing the courseware in Web form is so tutors can include in HTML documents they produce for their students hypertext links to specific pages of the courseware. Where the aim is to start at the beginning of a courseware module, hypertext links between a HTML document and the Web version of a module are made in a conventional way. Making hypertext links to take the user directly to specific topics or subjects located on a particular page of a module, is slightly more complicated.

Indexes provide users with a facility to jump directly to a specific page of a module. This is achieved using variables (that form part of each index entry), and passing them from one *Authorware* file to another. The current version of *Authorware* does not have built-in facilities for accepting variables passed from HTML coded web material. A work-around has been devised to do this, and while it works satisfactorily, links from a HTML document can be made in only a limited number of ways.

## Usage

The UKESCC courseware is being used well beyond its original brief; geology students at undergraduate level. About a third of the modules are widely used in schools and colleges where geology is studied at pre-university level. The courseware is also being used increasingly by interested amateurs, and people attending continuing education courses.

Parts of the courseware are used by students studying subjects like Geography, Environmental Sciences, Physics, Chemistry and Civil Engineering. To help users locate material relevant to such subjects, publications[8] and additions to the UKESCC web site giving details have been made. Reviews of some of the courseware are available[1,3] as well as evaluations[2,7].

## Discussion

The UKESCC courseware has been converted to Web format mainly for the benefit of users in educational institutes. The courseware is therefore now available in two formats; web and application format. The application format, normally supplied to users on CD-ROM, does not rely on Internet access and is popular with students working at home.

Content in several modules is beginning to become out-of-date, although this is not yet a serious problem. This is because much of the content is basic geological information which changes little with time, rather than the results of current research. Also, some of the early UKESCC modules are starting to show their age, with the layout, buttons, etc. starting to look old-fashioned. It is hoped the next upgrade of the courseware will address these issues.

## References

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## UniServe Science

Whilst originally set-up through a Federal Government Grant in 1994, **UniServe Science** is now funded by The University of Sydney through the College of Sciences and Technology, the Faculty of Science and the University Information Technology Committee.

**UniServe Science** caters for Biochemistry, Biology, Chemistry, Computer Science, Geography, Geology, Mathematics & Statistics, Physics and Psychology.

The activities of **UniServe Science** include:

- collecting information about teaching materials, finding out what is being produced in this country and overseas;
- disseminating all this information, by newsletters and electronic means;
- maintaining a web-based searchable database of information about teaching software;
- maintaining a web site which also includes information about discipline-specific teaching resources and links to other relevant sites;
- organizing to get new packages reviewed by teaching academics, and making these opinions available;
- setting up other exchanges of information by means of the Internet;
- recruiting representatives from every science department in the country in order to establish a nationwide network of direct personal contacts;
- undertaking visits to other institutions and giving talks; and
- holding workshops and seminars.

In addition to these, **UniServe Science** offers some services to local secondary science educators.

**http://science.uniserve.edu.au/**

## Council for Renewal of Higher Education

The **Swedish Council for Renewal of Undergraduate Education** was established by the Swedish Parliament on 1st July 1990, and became a permanent National Agency in 1993. Since 1st July 1995 the Council is an integral part of the National Agency for Higher Education. Since October 1999 postgraduate education is included in the Council's responsibilities which has led to a change of name. The purpose of the **Council for Renewal of Higher Education** is to promote and support efforts to develop quality and renewal of higher education. The three main activities of the council are:

- to award grants for development activities;
- to collect and disseminate information on planned, current, and completed development activities of a fundamental and innovative nature concerning undergraduate education in Sweden and abroad; and
- to evaluate the development activities the Council has funded.

Some specific objectives of the Council are to:

- support the integration of environmental studies in Sweden undergraduate education;
- support changes in curricula and pedagogy in Engineering and Natural Science programmes in order to recruit more female students to these programmes; and
- support the use of IT in teacher training.

Currently funded projects include "Hypermedia and Communications for Active Learning", "New Forms of Assessment in Mathematics and Computer Science", "Interactive Distance Education in Multimedia" and "Computer Assisted Education in Radiographic Techniques for Dental Students".

**http://www.hgur.se/**
**http://www.hsv.se/english/**

## Learning and Teaching Support Network

The **LTSN** has been established by the UK higher education funding bodies to promote high quality learning and teaching in all subject disciplines in higher education. The network supports the sharing of innovation and good practices in learning and teaching including the use, where appropriate, of communications and information technology.

The network consists of:

- 24 subject centres;
- a Generic Learning and Teaching Centre; and
- a programme director and coordinator.

Many of the new subject centres build on existing Computers in Teaching Initiative (CTI) Centres and involve learning and teaching support networks created by other funding council initiatives, such as the Fund for the Development of Teaching and Learning (FDTL). The new centres will become the main points of contact within subject communities for information and advice on good practices and innovations in learning, teaching and assessment, and will provide support for the many networks which already exist.

The GLTC will provide strategic advice to the sector on generic learning and teaching issues, disseminate good practice in the development and deployment of new methods and new technologies, and act as a knowledge broker for innovation in learning and teaching.

**http://www.ltsn.ac.uk/**

Attention : Susan Eshbaugh

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