Examples of Web-based Teaching in Physics

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In this article I describe examples of the use of web technology in my teaching of undergraduate physics subjects. Some of the developments, borne out of the opportunities provided by the World Wide Web, were admittedly led by the technology first and refined during their implementation. A number of the developments I describe have arisen out of identified student needs and are providing assistance in the development of students' understanding of core concepts and skills in Internet technologies.

Introduction

The use of web-based techniques such as asynchronous discussion groups, and interactive web-based multimedia is beginning to fill an important part of on-line learning strategies in university courses. The potential of on-line methods in the teaching of advanced science concepts has been realised[1,2] and is most effective when the strategies employed to involve students are well designed for the learner[3]. In this article I describe a number of developments including a virtual learning centre, an implementation of the "learning dialogues" concept using a newsgroup format, an interactive multimedia package for magnetism and an elegant solution to an emerging problem: writing mathematical notation on the World Wide Web.

Web-based teaching system

A hybrid web-based teaching system[4] was purpose built from freely available software running under the *Linux* (an Unix-like operating system for personal computers)[5]. The same server[6] hosts a number of single subject web sites as well as the Virtual Physics Learning Centre and support for web-based equation editing. The web site for each subject or student group is comprised of four categories of facilities:

- digital *resources* (notes/multimedia/solutions/hints)
- *interaction* facilities (email/virtual tutors/ newsgroup/chat)
- *administration* functions (scores/student profiles/ assessment tasks and deadlines)
- other *virtual* spaces (links out/web gallery/diagnostic centre)

Registration for the web site required the student had already obtained an email address (free through the University or from a commercial Internet service provider), and to complete an on-line registration form. The design of security and access modes makes each web site the electronic equivalent of a face-to-face class in so far as the interactions and resources are available only to registered members of the electronic classroom. In so doing, opinions and misconceptions expressed by individuals would remain within the group. Access to each subject/group web site is protected by server *htaccess* (username and password) control. The UTS (University of Technology, Sydney) student identification number, though somewhat impersonal, provides a unique 8-character username. Remembering passwords did provide difficulties.

Proprietary systems, such as *WebCT*, *TopClass* and *WCB*, that provide much the same features and functionality, are now available.

The student profile

As part of the registration for the web site students were asked to complete an on-line survey. The survey was intended to gauge their experience of, and confidence with, web-based technologies, as well as their access to the Internet and any concerns they might have about web-based teaching.

The profile of the students has been an ever-changing one. The data collected represents a snapshot in the first half of 1998 from a sample of N>175 students undertaking a physics subject:

On campus full time (i.e. greater than half load)	84 %
Have remote access to Internet (work or home)	57 %
Are engineering students studying physics	81 %
Fraction of the part-time students *with* remote access	78 %

Students' perception of their experience with Internet technologies was measured using a 3 point Likert scale. As can be seen in Figure 1, nearly all respondents claimed some experience in the core technologies of WWW, email and search engines. The majority of students however were not so experienced with email listservers and computer mediated discussion. (Care was taken to explain the meaning of these terms in the survey form).

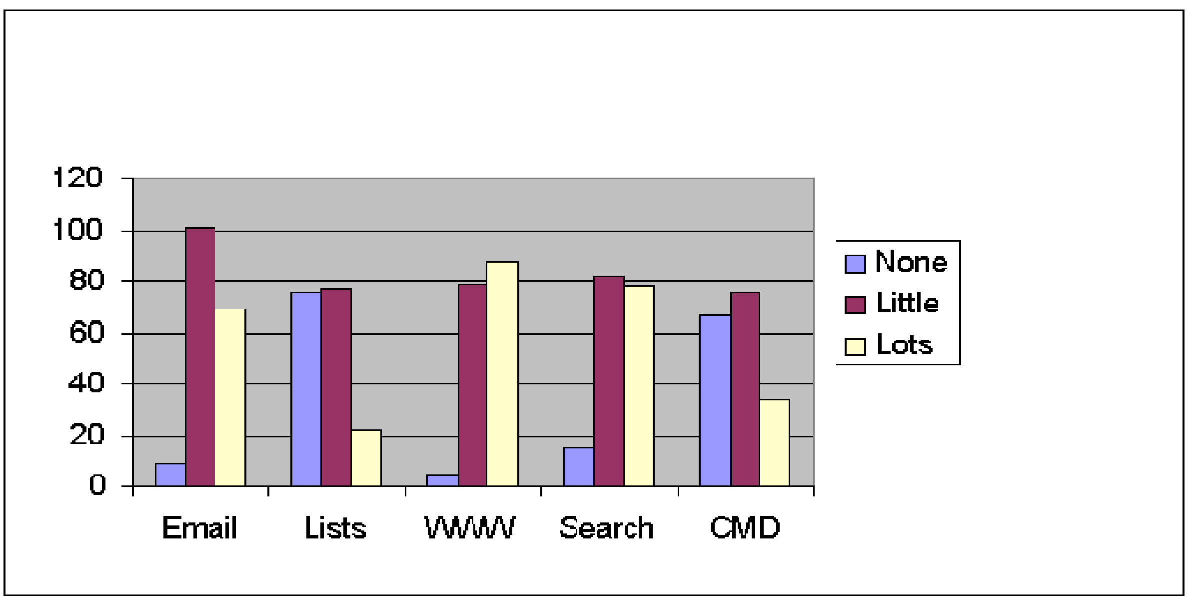


Figure 1. Students' ratings of their experience with Internet technologies (Lists=Listservers, Search=Search Engines, CMD=Computer mediated discussion)

Students' confidence with these technologies was also probed. It was possible that experience with the technology may not have ensured a confidence with its use. For instance this comment from an engineering student well into his/her degree and with ample experience of using word processing and spreadsheet packages for work:

> *I view myself as computer illiterate; hence I have little confidence in utilising the technology.*

The student responses however showed that in excess of 50% of respondents claimed to be very confident in the use of the core Internet technologies. Approximately 20% described themselves as not confident, but few described themselves as being worried about using the web.

Open feedback was also sought about any concerns they had at the outset:

> *It's going to make the course and/or assignments more difficult than usual.*
>
> *I've only used the Internet for fun so far, and I'm a bit hesitant about using it for coursework.*
>
> *I attend Uni. on ... only and I find using the web etc very time consuming.*
>
> *Call me old fashioned, however I prefer to learn from a human being.*

Strategies that will engage students in on-line learning activities must:

- recognise the range of experience and confidence students have;
- assist students who are concerned and/or might be left behind; and
- guarantee access to those who do not have ready access to the Internet.

Virtual Physics Learning Centre (vPLC)

The Applied Physics Department has for many years run a drop-in centre to which students can come to study. For several hours each day a tutor is rostered on to assist with any problems students have. The strategic initiative by the University into flexible learning prompted the development of a Virtual Physics Learning Centre (vPLC) to provide some of these same support functions but in remote mode. This is especially important for students who have difficulty attending at the rostered times.

Involvement in the vPLC is completely voluntary for students and staff. The Virtual Centre was advertised widely at class and on notice boards and as a result, was well supported (approximately 40% of eligible students and 25% of staff). The main emphases of the Virtual Centre are:

- to provide equity across different strands of new first year subjects;
- to provide an avenue for timely updates, corrections and advice;
- to facilitate some self-help with on-line diagnostics and FAQ's; and
- to provide one-to-one help (Virtual Tutoring) and interaction with fellow students.

The vPLC web site has the same generic structure as that described for the web-based teaching system. An important challenge in such a facility is the need to keep the web site looking fresh in order to encourage frequent visits from students (without enormous time input from the manager). One strategy employed was to include a highlight box that could be easily changed weekly (or even daily). The highlight box was produced using a "server include" - a small dynamic element within an otherwise static web page. An example is shown in Figure 2. An analysis of pathways taken by students through the web site showed that many would follow the link in the highlight box, and then dig around for other resources. Overall the first year students were most often downloading hints and solutions to worked problems (which were made available in a trickle through the semester). They were reluctant to get involved in on-line discussion of open questions and rarely used the email list facilities. Staff noticed that they tended to receive individual emails from students in their face-to-face class, instead of the more anonymous "Virtual Tutor" route.

Figure 2. Screen from vPLC showing the message banner at the bottom

Feedback such as the following comments highlight the benefits (perceived by students) of having 24 hour remote access to resources:

> *Hi it's [me] again, as I pointed out in my mail before I think that the vPLC helped me out heaps and if it wasn't for it I think I would have not got the mark I received. Before the physics exam there was not enough time to go to Uni., find a physics lecturer and try to work out answers with him/her. The vPLC was a perfect solution (for those with access to the Internet of course).*
>
> *I would like to thank you for the effort you put into the Virtual PLC - I found that it really helped me out with the physics work I had to do.*
>
> *Just wanting to thank you for the vPLC as it has been a great help in my study for this final Physical Modelling exam. I've mainly used it for the worked answers and the corrections to the answers It's been a great help.*

On the other hand, the web server statistics shown in Figure 3 paint a somewhat grim picture for student study habits in the lead-up to the final examination. The two tallest vertical bars in the graph correspond to the days prior to each of the first year physics examinations.

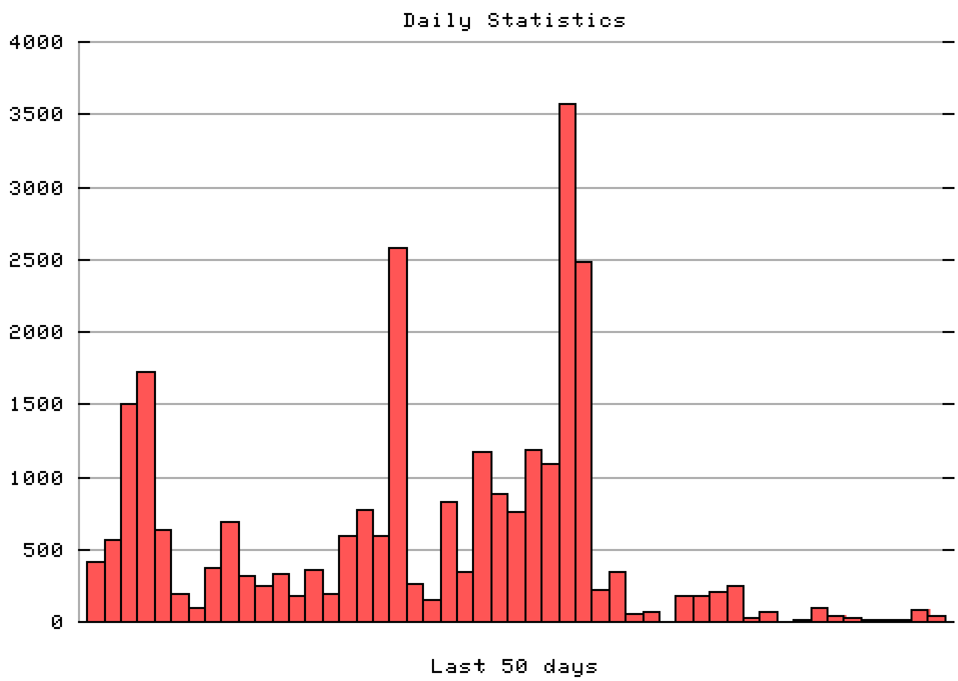


Figure 3. Daily server activity commencing (on the left) with the last week of semester and continuing past the end of the examination period. Each vertical bar represents the number of server "hits" (html documents and images) in each day.

Encouraging learning dialogues with newsgroup software

This work has its origins in the many emails to and from students that were most often of an administrative nature. However amongst this correspondence there were genuine attempts on the part of students to formulate mature questions, and to provide reasoned "self-answers" inviting comment. The benefit of this *semi-formalised* "thinking aloud" has been recognised as an important attribute of computer mediated discussion.[7]

Open feedback was sought from students as they embarked on the learning dialogues project. In particular they were asked about their interest in web based learning:

> *My interest in Internet based learning would be solely on being a discussion group. We can use this session to discuss the problems encountered during lectures and perhaps come up with answers for them.*
>
> *The Internet is the future and I find it quite useful and efficient in the amount of time it saves you and you can get some good information from it if you know where to look.*
>
> *Internet and interactive learning is a "hands on" teaching practice and enables the user to dictate the pace and content of material learnt. My interest lies in the Internet as a teaching tool.*
>
> *To have the flexibility that Internet based learning offers. The attendance at lectures can be difficult for people who are working and studying part time.*
>
> *I think that it is a very good idea because Internet access is accessible to everybody, and you can go in and study outside specific lecture times. As well as this, for example, if you had a problem with homework, prac. report or so on, rather than waiting until tomorrow to seek the aid of a lecturer/demonstrator, you can just log on and (hopefully) solve any queries.*
>
> *Trying to stay with technology and its advantages.*

These comments suggest a willingness on the part of students to "give it a go", and perhaps some subscription to the hype about the future of Internet-based learning. In this section I describe a strategy to utilise asynchronous discussion techniques and to engage students in a significant learning task.

A strategy has been developed to engage students in dialogues with each other, with the teacher, and importantly, internally with themselves. A teaching and assessment strategy has been developed that engages students in "thinking aloud". The asynchronous discussion format provides a flexible and interactive vehicle for this thinking to take place. A small number of key concepts in the subject are dealt with in this way.

The important elements of the strategy are:

- open questions as the stimulus (room for interpretation in question and answer);
- exploration of the question can usually take place at several levels;
- each question (module) starts a fresh newsgroup;
- questions are set as prework for next class (often revision of earlier studies);
- virtual tuition (comments/arguments) from peers or teacher;
- self review later in semester; and

- participation in the discussions forms a small part of the assessment.

Newsgroup software (*HyperNews*) which supports multiple threading and indentation of responses was used for its simplicity and robustness. The software supports a variety of modes for the attachment of messages including a "smart text" as well as HTML and the embedding of entire URLs.

Figure 4 shows schematically the life cycle of a module down the right hand side with the key teacher inputs on the left. A module will remain "active" for at least four weeks to allow stragglers to complete (commence) the module. The input from the teacher feeds in, where necessary, to ensure discussion proceeds productively. Critical stages have been found to be just after the module stimulus is posted, and at the end, when contributions from students are synthesised into a summary record. To encourage student involvement, the students' participation in modules is assessed. The weekly activity, amounts to 5% of the subject assessment, and is assessed primarily on participation. To ensure that all students had the opportunity to consider the prework modules prior to class, a computer laboratory is made available immediately prior to class.

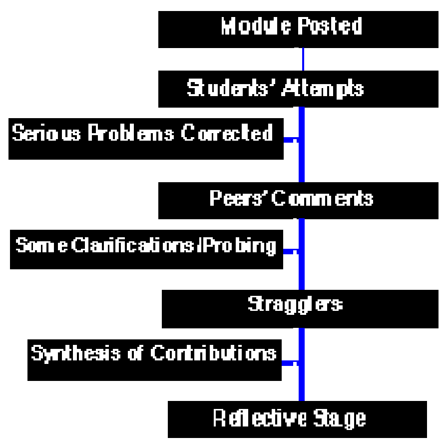


Figure 4. Schematic diagram showing the timeline of a learning dialogues module. The involvement of the teacher at key points in the process is shown as inputs from the left.

Some implementation issues arose. Although the newsgroup format encourages interaction, a good answer, early in the thread of responses, tends to kill discussion. The role of the teacher here is to draw out some broader issues to keep the discussion fuelled, e.g. by seeking clarification from individuals who seem eager to agree with the previous person.

In a prototype system, students were not aware of other students' responses prior to submitting their own answer. Instead, new responses were incorporated into the newsgroup database using purpose written CGI scripts that returned to the student's browser, a sample of the previous responses and the invitation to comment. There are a number of pros and cons for the two approaches. For example from a student's point of view "does it feel like a discussion?" or "does it feel like a test?"

The learning dialogues project has been evaluated at various stages and at two levels, namely technical and in respect of intended learning outcomes. At the technical level, there are questions and issues like:

- from the early days (1995) almost half had some form of remote access (at least a text browser available by dialling up the Unix systems);
- bookings of computer labs for prework required staff supervision to ensure those students got the access;
- on-campus availability was poor at other times; and
- the prework took much longer than staff expected.

At another level, there are the learning outcomes:

- learning dialogue tasks helped with understanding content;
- most found it somewhat difficult to express scientific ideas in words;
- difficulty finding topics prior to the lecture;
- Virtual Tutor was not helpful when being deliberately vague; and
- there was measurably better performance on questions in the final exam relating to the conceptual understanding of the issues raised in the on-line work.

A reflective activity, utilising the on-line discussion software was also developed that involves the communal compilation of the "Hot100 Topics". Contributions from students and staff can take the form of questions/pleas for help/checks on sanity, with replies in the form of peer answers/comments/advice. The evolving archive of students' contributions provides considerable insight into the students' grasp of the subject matter.

Doing mathematical notation on-line

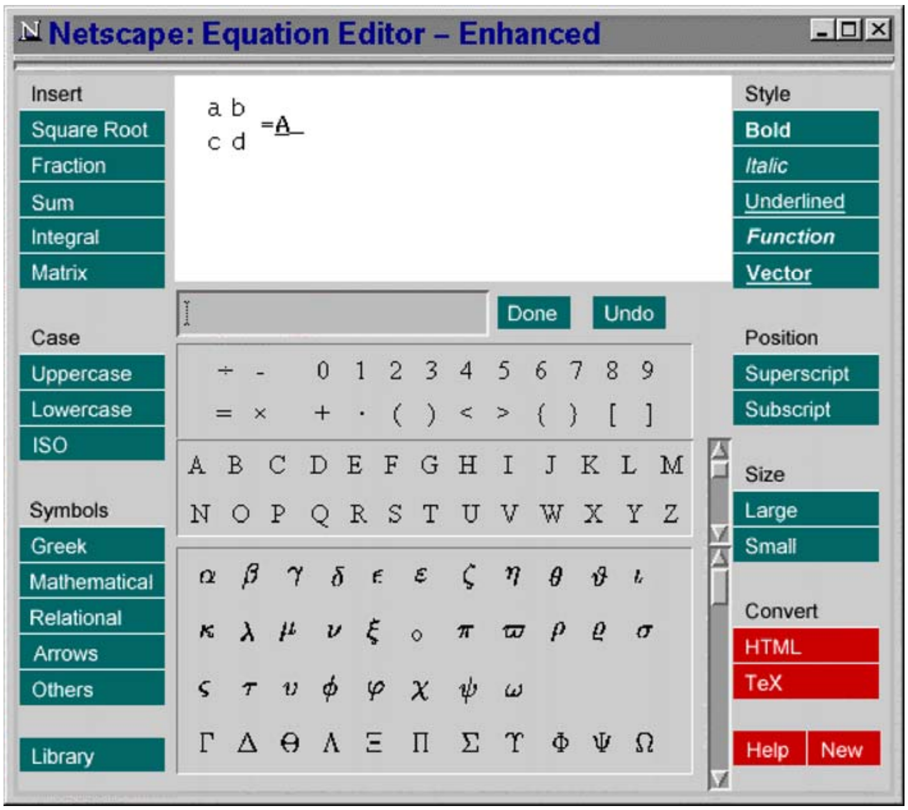
Disciplines such as physics, mathematics and engineering (those in which the use of mathematical symbols and equations are an essential part of communication) are presented with an extra hurdle in the development of web-based teaching materials and strategies. Although there are several ways to produce web compatible mathematical notation they nearly all make the tacit assumption that you will write your bit of mathematics once, put it onto a web server and then leave it alone. These methods include:

- writing them out by hand and digitising the page;
- typesetting the mathematics using a word processor (Save As HTML);
- using a *Mathematica (V3.0)* Notebook and exporting as HTML or LaTeX; and
- using LaTeX and embedding in web pages or converting to HTML.

The use of on-line discussion tools in technical disciplines presents an immediate difficulty. None of the methods outlined above is appropriate to the fully interactive situation such as a hypertext chatroom or asynchronous discussion. There is a need to interactively compose and use mathematical notation within the web browser, easily and quickly.

An interactive web-based package for composing scientific equations has been developed at UTS (University of Technology, Sydney) as part of its flexible learning initiatives. As this goes to press it is the only realistic option for producing mathematics for the interactive web applications ("on the fly") without the need for special plug-ins, peculiar syntax, or access to an on-line database of special symbols.

The package is browser based and has an intuitive interface (see Figure 5) and handles symbols, superscripts, subscripts, integrals, summations as well as matrices. The equations get rendered in (what you see is what you get) HTML as they are composed. The final output can be in the form of HTML (Figure 5) or LaTeX or, after server processing of your request, an inline GIF image which can be saved on your local machine or pointed to by its URL on the server.



Regression Sample shown as html

$$y = a + bx$$

$$a = \frac{\Sigma x^2 \Sigma y - \Sigma x \; \Sigma xy}{n \; \Sigma x^2 - (\Sigma x)^2}$$

$$b = \frac{n \; \Sigma xy - \Sigma x \; \Sigma y}{n \; \Sigma x^2 - (\Sigma x)^2}$$

Figure 5. Screen grab of the web-based equation editing software control panels, together with a sample of HTML output produced

A novel use of guest book software

Towards the end of the semester one other web-based activity is introduced. It utilises a "guest book" type package to create a student created list of relevant links to the World Wide Web. As part of the learning activity, students are introduced to search engines and how to use them and asked to find a credible URL on the Internet and to *explain* the relevance of their finding to the subject matter. Over several semesters this has developed into a valuable resource for students and teachers alike. A sample of the sorts of contributions made to it under one category of topic is reproduced here:

- Domain Wall Motion has been contributed by Dave *because* it shows examples and excellent graphics as to how domain walls move and examples of where it is undesirable.
- NOVACAP's Technical Brochure: Ferroelectric Ceramics has been contributed by Jenni *because* it provides a good summary of ferroelectric ceramic characteristics and takes the subject just a bit further than what's done in class. It also concentrates on barium titanate, which is of interest at the moment, but discusses the advantages of using other ferroelectric ceramics instead.
- How Things Work: Magnetically Levitated Trains has been contributed by Iain *because* it helps to summarise some of the magnetic section of the subject.
- Superconductor Levitation Movie has been contributed by Budiman *because* it is relevant to our project.
- Magnetic trapping of ultra cold molecules has been contributed by David *because* it answers Evelyn's question about whether all magnets are solids.

MagSim: An interactive web-based multimedia development

A number of scientific concepts need to be described **both** in terms of the macroscopic behaviour they exhibit and in terms of the microscopic processes which underlie the phenomena. Genuine understanding of these areas of science requires that the learner move comfortably and confidently from the macroscopic to the microscopic realms. The causal connections between the macroscopic and microscopic realms are all too often made only superficially with the "complete picture" remaining distressingly unclear.

The magnetic properties of materials are a prime example of this type of macroscopic-microscopic duality. The use of computer simulation to help explain magnetic behaviour by *simultaneous* display of microscopic and macroscopic realms has been an ongoing development.[8,9,10]

An interactive package called *MagSim* was developed originally for Silicon Graphics workstations[11] and allowed small groups of students access to the software. The emerging popularity and footprint of the World Wide Web provided the impetus for a rethink of the mode of delivery of *MagSim* to students. The use of web browsers provides platform independent access to the suite of software. The existing simulation code runs as is on the workstations. The relationship between browser and workstation code is illustrated in Figure 6. The main challenge in the conversion process has been to create web browser compatible graphics "on the fly" and return them as an embedded *QuickTime* movie (see Figure 7). Graphic design support[12] was crucial to the production of an interface that was compatible with "lowest common denominator" web browsers.

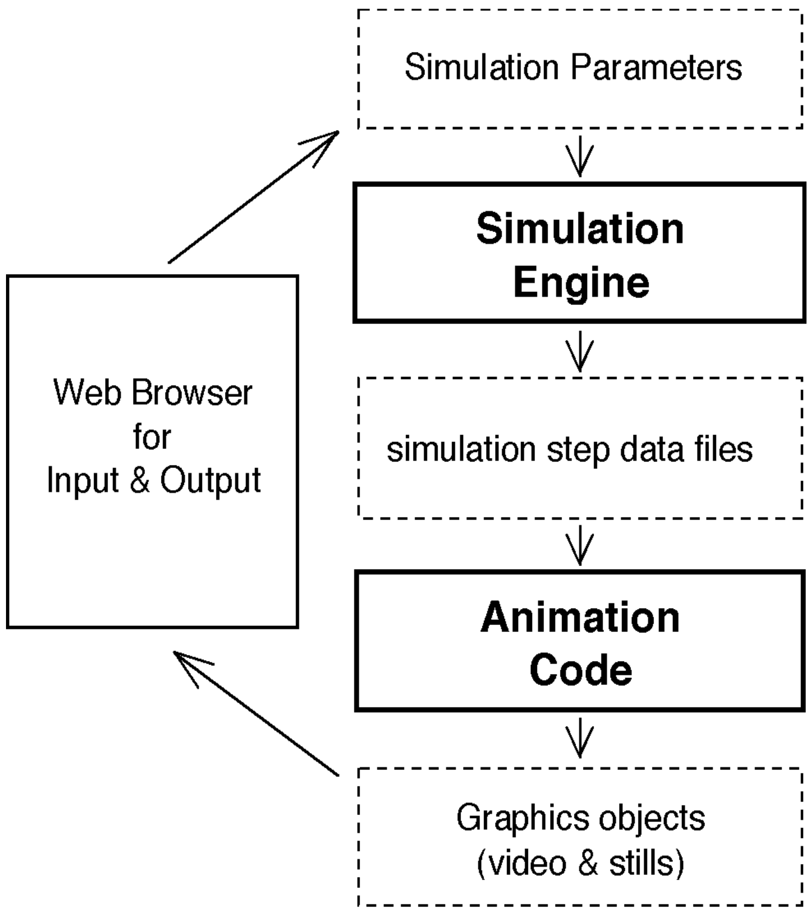


Figure 6. Role of the CGI interface in providing access to and results from the complex simulation software. Output in the form of pictures gets sent back as an animation into the web browser.

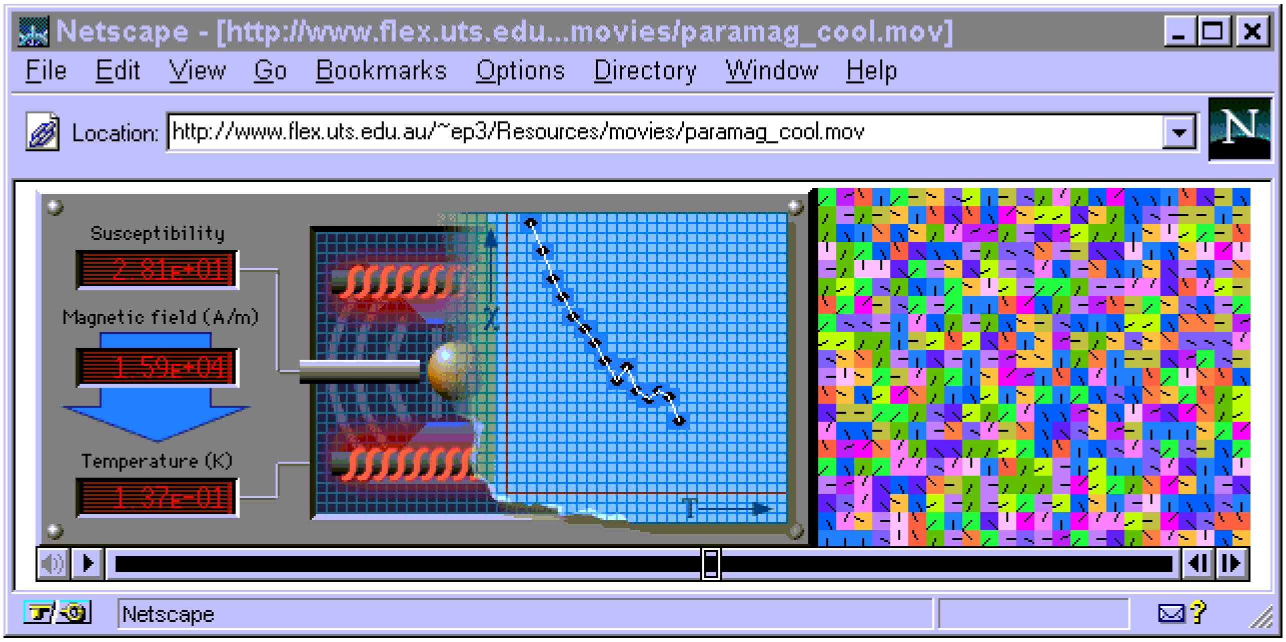


Figure 7. ***MagSim*** **video animation used as stimulus in a web-based assignment**

Fully interactive use of the package has proved to be too slow for regular use, especially for off campus access. A pre-packaged set of animations has been produced that students can then analyse in a web-based assignment/revision class.

Summary

This paper has described several aspects of my activity in web-based teaching in physics. The generic features of a system for supporting the range of facilities required of an on-line teaching space were with the reminder that commercial packages are available that can be used for the purpose. A snapshot of the students that have been involved in these developments has been presented along with the features and functions of the Virtual Physics Learning Centre that the majority of them were registered for. A strategy to engage third year physics students in on-line discussion of core concepts has been presented. A pair of interactive browser based packages have been developed, one motivated by an identified need in students misunderstanding of magnetism, and the other motivated by the practical issue of communicating on-line using mathematical notation.

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