Activating the Web as a Virtual and Dynamic Learning Environment

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Abstract

In some subject areas the fusing of theory and practice can only be accomplished by demonstrating fundamental principles and their application via laboratory experiments. Although the benefits of underpinning the key conceptual and theoretical aspects with laboratory work have long been recognised, the practical and logistical problems associated with organising laboratories often results in students not fully engaging in the educational process. Unfortunately, many traditional laboratory experiments lose their impact if students are not fully prepared or appreciate the value of experimentation as an essential component in the learning process.

The advent of the WWW provides a tremendous opportunity to address some of these issues through the provision of 'virtual' laboratories where students are able to access the facilities at any time. However, the design of these information rich environments requires web authors to 'activate the Internet' through the inclusion of a range of dynamic features if the on-line learning resources are not to be static and unchanging. These tools and technologies offer unlimited possibilities in the design of virtual worlds and the development of interactive Web sites. Through the use of a case study, this paper will discuss the design of a virtual laboratory and present a range of strategies for developing dynamic and active learning material for transmission over the Internet.

Introduction

A virtual laboratory can be defined as **"a computer system that models a place, situation or the like conductive to experimentation, investigation or observation"**. The advent of Dynamic HTML (DHTML) has provided the infrastructure for Web pages to go beyond static text, images, and hyperlinks and become truly dynamic. With the cost and safety of laboratory classrooms an important consideration, virtual reality laboratories offer the opportunity for students to have unrestricted access to experiments in a highly interactive and information rich environment. It is of course essential that in any given discipline the correct balance should be found between simulated and real-world experience

A review of the literature (see Boud *et al*, 1984) suggests that the main aim of laboratory work should be to teach inquiry methodology and experimental design. It is often also reported that students do not enjoy the activity and therefore do not appreciate the main aims of establishing the links between theory and practice, to aid visualisation, and to develop team-working skills. In the case of student laboratory work, the information required will be somewhat different than that obtained in the workplace, in that the work will not be needed as part of an overall investigation but will be a single exercise intended to familiarise the student with test equipment and methods. As such, more emphasis should be given to the equipment layout, the test procedure employed, the calculations and the difficulties encountered.

Although the symbiotic relationship between theory and experimentation is explored in lectures, seminars and tutorials, it does not however impart competence, nor prepare the student for undertaking various types of experiments. The student's first encounter with a laboratory and its surroundings can be quite daunting, particularly when the types of equipment varies enormously. Additionally, the functionality of the apparatus and the method of use for particular experiments has its own learning curve that is rarely acknowledged in the learning experience. *"All too often practical classes can degenerate into routine procedures of following instructions and writing up results – activities which if not administered carefully can lead to students wasting a great deal of time to little educational effort"* (Hicks, 1997).

The **ATLAS** Project (Academic and Technical Laboratory Assistant) aims to address these problems by providing students with a 'virtual' laboratory that allows them open access to the facilities. The virtual laboratory allows students to explore the facilities in more detail so that they can immerse themselves within the virtual world and access knowledge in a variety of ways. Students can access technical information to assist them in writing up their experiments or view video clips of the key stages of a particular experiment. Such facilities have no time frame or restrictions on access and therefore students can observe the procedures as many times as they wish. The WWW provides the opportunity to fully integrate both theory and practice in a highly interactive environment thereby supplementing the traditional lectures.

The Problem

Soil mechanics and materials testing is studied on a variety of undergraduate and technician programmes within the University of Derby including building technology, civil engineering, construction management, geology and geography. Whilst the focus and the types of experiment undertaken by each discipline may differ, the learning outcomes associated with laboratory work are similar and well defined. That is, students should be able to

- appreciate the need for the laboratory testing of soils;
- select appropriate tests from the range available for assessing soil properties;
- appreciate the need for diligence, accuracy and general awareness of possible difficulties in all laboratory work;
- analyse and interpret laboratory data;
- write a clear and concise report of the work undertaken comparing and contrasting it with published data.

In the United Kingdom the experimental procedures relating to the methods of test for soils for civil engineering purposes are set out in British Standard 1377 (1990) and initially it is these procedures that form the basis of the ATLAS Project. A review of laboratory experimentation within the Division of Construction revealed that students experienced difficulties in being able to relate the written procedures to the equipment due to having no visual appreciation of the laboratory or the apparatus. To assist students with their experiments and provide the necessary cues and prompts a demonstrator is always present. Where groups are experiencing difficulties, the demonstrator will extend their role to that of instructor carefully guiding the group through the experimental process but avoiding becoming an additional member of the group. This instructional aspect of laboratory work is particular important and is seen as a key feature that ATLAS should incorporate.

Prior to commencing ATLAS, feedback was sought from both students and staff. From this it was concluded that if laboratory experiments are to be valid and worthwhile, students need to be able to visit the laboratory prior to its commencement and also have the opportunity to revisit so that they are more capable of relating their results to expected outcomes. The

inclusion of virtual experiments was considered to be an important component of ATLAS to promote knowledge construction and extend the student's existing understanding. At present it is not conceivable to contemplate the simulation of an entire teaching laboratory. The technology is not sufficiently advanced and computer networks are often too slow and prone to sporadic failure. The best that can be achieved at the moment is modelling fairly small groups of experiments (Harrison, 1998, Raphan, 1998, Senese, 1998). Investigating what is feasible and most appropriate for student learning is one aspect of ATLAS and feedback from end users will influence how virtual experiments will develop in future versions of the Web site.

Having defined the range and type of experiments to be included in ATLAS, it was decided that the computer-based 'virtual' laboratory should include the following key features:

1. Availability over a local Intranet and/or the Internet.
2. Web documentation accessible from CD-ROM for those students without WWW connection.
3. Navigational walk through facilities.
4. Technical information underpinning the laboratory experiments.
5. A procedural statement for each experiment.
6. Interactive calculation forms for processing experimentation results.
7. Photographic images of key equipment and apparatus.

The ability to easily modify ATLAS to include further experiments at a later date, and to adapt it to for other disciplines and laboratories, was considered to be particularly important.

Design for Web-Based Learning

Soil mechanics is taught through a combination of formal lectures and laboratory-based exercises. In the former, students are encouraged by the tutor to engage in a constant process of active learning, constructing new ideas based on their current understanding of the subject and relating this to their previous and ongoing studies. In the latter, students acquaint themselves with laboratory procedures primarily through the medium of instruction and collaboration with their peers. It was therefore important that ATLAS would be capable of simulating these different learning environments and that the resulting Web site would have both a thoughtful interface and instructional design which work together. So how can this be achieved?

Motivating the learner

The visual impact of a Web site is particularly important in retaining the interest of the user. We are notoriously fickle and our attention keeps shifting in the pursuance of ever more interesting links and heightened experiences. A badly constructed or lack lustre site has little chance of making any impact and it will probably be consigned to the cyber-dustcart. In designing ATLAS considerable thought was given to its visual layout and how this could be related to the concept of knowledge exploration in the technological age. Rather than have the user walk through the virtual laboratory in a pedestrian way, it seemed more in keeping with Web technology to situate the user at the controls of a starship exploring new worlds with new experiences as shown in Figure 1. This helps to redefine the laboratory as a place that is interesting and not just a room filled with inanimate equipment.

Figure 1 shows the layout of the user interface where students can navigate around the laboratory, access information through a contents page or an index listing, collaborate with others using a bulletin board or make use of utilities such as an on-line calculator. The main screen is divided into four key components.

Figure 1. *Main user interface showing the layout of ATLAS*

The top left-hand corner of the screen is used to present a photographic visualisation of the laboratory allowing the student to navigate through the virtual world. In the centre of the screen is the tab strip menu that provides access to a range of features including the contents page, an index, a bulletin board, on-line help, etc. The right-hand portion of the screen is used to present the learning material. The learning material is linked both to the contents page and the index with each being made visible by clicking on their respective tabs. The bottom right-hand corner of the screen contains the navigation panel that allows the user to walk through the laboratory.

Identifying what is to be learned

Developing a navigation flow that users can follow easily without getting lost is a critical design requirement for any Web site. If links to Web documents are not intuitive the site can easily become the stage set for 'Dungeons and Dragons' resulting in a complex labyrinth. If information is not easy to obtain and the student has to work hard to locate resources, the effin factor (an effort-to-interest trade-off) will increase and students interest will wane (Berline, 1960). Navigation within ATLAS is twofold; firstly, the student is able to locate themselves within the virtual laboratory and have a sense of its size and boundaries; secondly, the menu structure and linkages between documents directs the student along a carefully sign posted route that takes them from the beginning to the completion of their studies.

The contents page has been designed using *Microsoft's HTML Help* software and uses a book metaphor with chapter headings and page titles. Identifying what is to be learned is achieved by providing a well structured and clearly defined sequence of learning based on the topic headings used in the majority of soil mechanics textbooks. For each of these topics, a sub-menu system (see Figure 2) is presented.
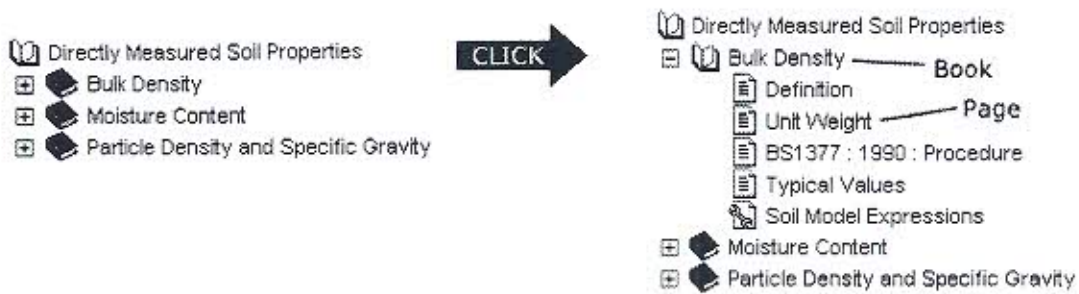
Figure 2. *Table of Contents*

Reminding users of past knowledge

The ability for students to be able to retrace their steps and return to information that reminds them of knowledge they previously learned is what makes the WWW so attractive as an educational tool. ATLAS incorporates links to other Web pages and pop-up windows that act like post-it notes jogging the student's memory to previous knowledge and maybe suggesting new directions of enquiry. It also provides (through its visual interpretation of the laboratory) a means of linking to a wide range of information by incorporating hotspots that can be interrogated by the user. For example, moving the cursor over a particular piece of equipment (see Figure 3) provides additional information. In this way, each photograph can be dynamically programmed to provide a wealth of information and allows the student to build up a complete visual picture of the laboratory, its facilities and how these relate to the experimentation procedures.
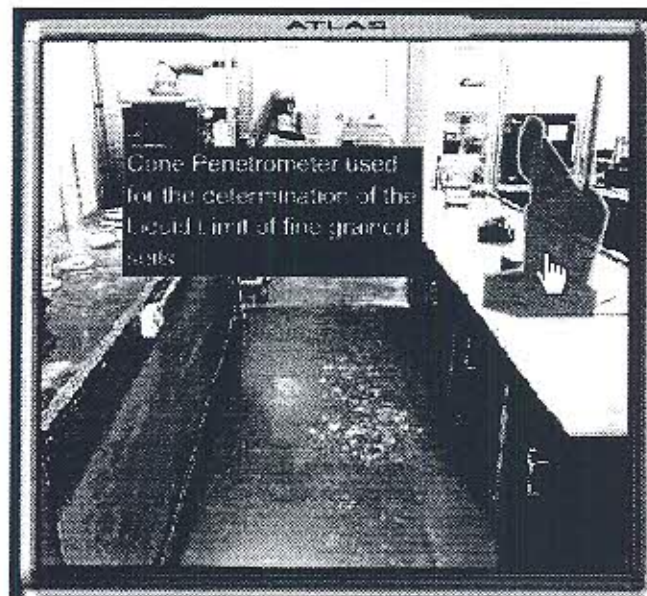

Figure 3. *Dynamic interaction*

Providing guidance and feedback

Guidance and feedback is an important component in any educational strategy providing individual students with a deeper explanation of their choices which guide them to additional information. ATLAS uses clearly labelled links that guide the student through the myriad of potential routes. Pop-up textboxes are used as a useful adjunct to hyperlinks, providing guidance and helping the student to identify other sources of information. Feedback is given

through programmed learning activities such as in-line assessments or multiple choice quizzes. These help to reinforce the student's understanding of the topic and allow them to monitor their progress set within a learning time frame that is controlled by themselves.

To help students familiarise themselves with the various facilities offered by ATLAS, a virtual tutor is on hand to give a guided tour. Merlin the wizard (see Figure 4) is a *Microsoft Agent Control* with sophisticated animation actions that can be programmed to provide guidance in ways that are engaging and potential educationally stimulating.
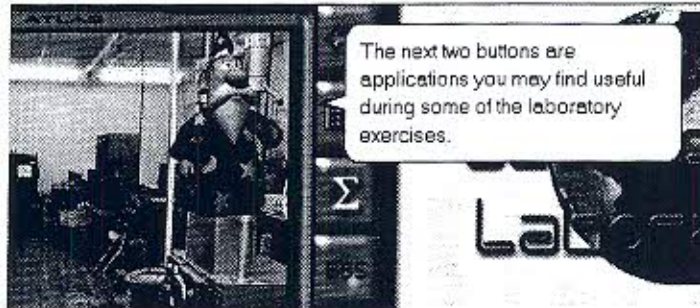

The next two buttons are applications you may find useful during some of the laboratory exercises.

Figure 4. *Merlin the Wizard*

For users with full multimedia facilities, Merlin has been programmed to include speech output helping to simulate tutor interaction. Merlin could be programmed to offer alternative solutions, question student responses based on some input, suggest links to further information or automatically load other web documents.

Testing

The testing of knowledge is an intrinsic component in monitoring the progress of a student's performance whether it be formative or summative. This helps both the tutor and student to clearly identify areas of strength and weakness and modify the learning programme accordingly. Whilst recognising the limitations of the Web (formulas cannot be directly input for example), a range of assessments have been incorporated within ATLAS from quick quizzes (see Figure 5) to tutorial questions with hints and worked solutions.

Quick Quiz : Cohesive Soils – Important Indexes

Match each definition with its corresponding equation by dragging the equations to the boxes using the mouse

1. Liquidity Index $W_l - W_p$

2. Plasticity Index $\dfrac{I_p}{J}$

3. Activity $\dfrac{W_l - W}{W_l - W_p}$

4. Consistency Index $\dfrac{W - W_n}{W_l - W_p}$

Figure 5. *Typical Self-Test*

Providing enrichment and remedial opportunities

The final step in many instructional programs provides learners with either remedial opportunities (in areas where comprehension is lacking), or enrichment (featuring associated information which extends or applies their knowledge). In determining the route that the student would need to take would require some means of assessment as discussed in the previous section. For example, a student achieving a low score in a specific segment of instruction may

be guided to additional supportive information, while the high scoring student may be challenged with a more demanding array of questions. For the purposes of evaluation, a range of learning activities have been incorporated within ATLAS including a virtual experiment, tutorial questions including feedback suggesting areas of further/supportive study and interactive calculation forms to assist students in processing their laboratory results.

Evaluation

An evaluation of ATLAS is currently being undertaken. However, initial feedback from academic staff has been very positive. All have commented favourably on the aesthetic layout of ATLAS and the ability to navigate through the laboratory in a highly interactive manner. Users were surprised and impressed with the facilities that can be created with DHTML and the way in which it liberates the developer from the rather limiting and somewhat lifeless web pages created using HTML.

The ability to embed multimedia and calculation forms into web pages has generated considerable interest and its potential has been quickly recognised. The author is aware that ATLAS requires further refinement and this is a part of an on going process. These refinements can only enhance ATLAS and provide the students with a very rich learning environment that maximises the potential of the WWW.

Conclusion

ATLAS has been developed on a modular basis and hence the potential for further development is considerable. It has been designed to allow other academic staff using the laboratory to develop their own learning material to suit their style and preferences. The potential for this project to be extended and developed in other areas of experimentation are significant and the long-term objective is for ATLAS to be able to link to other laboratories. This would considerably enhance the software and would be the basis for the development of a modular suite of programs. Considering that there is a dearth of student texts on undertaking laboratory experiments, software such as ATLAS could help to bridge the gap between theory and experimentation and thereby enhance the student learning experience.

To maximise the potential of the Internet, developers need to harness the power of DTHML, Javascript and multimedia if they hope to provide a truly interactive environment . The benefits of DHTML are many. Information can be presented in a more compelling manner, interfaces can be more responsive and easier to use, and new types of applications previously found only on CD-ROM are made possible. This will bring the web to a new level in the same way as HTML moved it from text-based information to images and hyperlinks.

The foundation blocks of the virtual laboratory have been laid, the walls are in place and the roof is securely fastened. With time it is hoped that this virtual environment will be full of rich learning experiences that provide students with a range of strategies for acquiring new knowledge in different and exciting ways.

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