

Incorporation of a Demonstrator into Internet-Mediated Laboratory Experiments*

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A new form of interactive Internet-mediated science/engineering practical class that can be conducted by students from any campus within a hosting multi-campus university has been developed using readily affordable technologies. Unlike existing computer-aided learning packages and Internet-mediated practical classes, this new teaching/learning tool incorporated direct two-way voice demonstrator–student interactions. This combination of computer-aided learning and the more conventional real-time demonstrator-guided learning drew benefits from both modes of teaching and learning to produce an enhanced alternative to practical class delivery.

INTRODUCTION

MULTI-CAMPUS universities are becoming increasingly prevalent, with many subjects now being taught simultaneously across campuses and even institutions. While the theoretical component of technical subjects can be readily delivered cross-campus through various mechanisms, space restrictions and high capital costs place significant limitations upon the essential practical component of any technically based educational program. For this reason, educators continue to seek practical activities that can be undertaken away from the traditional face-to-face laboratory environment in order to maintain essential high educational standards.

Alternatives to the traditional hands-on practical class include a wide variety of computer-aided learning packages [1–5]. Waller and Foster [6] developed a computer-based education web program whereby students learn to operate a virtual instrument outside a laboratory before actually using it in the laboratory. This educational tool employed captured images to educate users on how the device actually worked and how to use it. The developed package significantly improved use of the real instrument, as users' hands-on learning time was significantly reduced. However, while this approach permitted more efficient use of laboratory time, students are still required to attend the actual laboratory site to gain real-time and hands-on experience. The real-time component should be considered important, as its immediacy better replicates real-life systems, where problems can be encountered and solutions rapidly sought.

Recently, real-time Internet-mediated practical classes (RTMPCs) have been developed and incorporated into educational programs [7–11]. In this form, laboratory class students are able to control an experiment in real time over the Internet, using a computer-controlled interface (usually based upon an HTML frames website). Students view the outcomes of their chosen actions (which may include increasing the flow rate of a pump) via images transmitted to the student computer from a camera focused on the experiment and/or through digital readouts also displayed on the student's computer screen. From the data collected, the students can report on their experimental findings, as they would have been able to use the traditional hands-on experimental laboratory. It is recognised that this form of experimental delivery system lacks hands-on experience, but, as recognised by Florance and Lemckert [9] and presented in Table 1, many of the aims of the practical class are still achieved. It is also important to consider that engineers will be working in environments where remote machine operation is the norm (e.g., water treatment plant control rooms) and, therefore, some laboratory excursions should focus upon remote operations.

The major drawback of currently available alternate forms of laboratory class delivery is that they do not allow for the inclusion of a real demonstrator into the learning process. For example, Fig. 1 depicts the idealised communication paths between the students, the experiment itself and an active demonstrator within a practical class. Here an active demonstrator refers to someone who encourages and guides students through the learning process, while at the same time asking and answering appropriate questions relevant to the learning exercise. Indeed, Hedley and Barry

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Table 1. General aims of practical laboratory work through on-line experiments (reproduced from [9]). The asterisks indicate the relative accessibility of aims using a scale of zero to five asterisks, while the crosses indicate the possible improvements made with a demonstrator included in the process

General aims of engineering laboratory practical work	Accessibility
To support the learning of theory	
• By illustrating/demonstrating phenomena	****
• By applying theory to real situations	*****
• By demonstrating the limitations of theory	*****
• By interacting with phenomena in authentic situations	****
To develop a body of knowledge	
• About materials, devices and techniques	***+
• About safety codes and practices	**
• About specific equipment and techniques	***+
To develop a body of skills involving	
• Manual skills	—
Critical observation, interpretation and assessment	****+
• Diagnostic skills	****+
• Planning and organisation	**
• Practical problem-solving	*+
To develop attitudes which	
• Stimulate an interest in engineering	****+
• Highlight 'getting the job done'	***
• Generate self-confidence in all areas	***+

[12] and Nuldon [13] found that demonstrators are crucial in ensuring good student learning outcomes.

The interactions that occur in RTMPCs are significantly different from those within the traditional laboratory. As shown in Fig. 2, the communication paths in RTMPCs are primarily one-way visual to the student with the student having control over the experiment. Besides information supplied through printed or electronic resources (such as supporting web pages), the student has no external stimulation to enhance the practical experience, as they would encounter if a demonstrator were present.

This paper will discuss and introduce a new Internet-mediated laboratory methodology that has been developed in order to enhance student learning. Importantly, this new Internet-mediated system incorporates a demonstrator into the learning/education process. The paper will first discuss the need for the inclusion of a demonstrator and the method by which this was achieved. Results from student feedback and external observers will then be discussed. The developed system used readily available and affordable technologies, meaning that it can be easily introduced into the teaching environment.

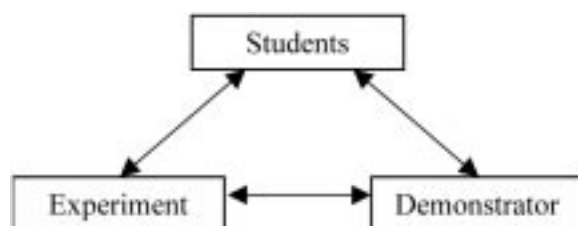


Fig. 1. Schematic of traditional laboratory experiment interactions. The interactions can take various forms of sensory interactions, including verbal, visual, control and touch.

THE NEW EXPERIMENT DESIGN

Hands-on experiments often incorporate a demonstrator into the activity in order to assure safety and the opportunities for guided learning and student stimulation through immediate feedback to student questions and observations [12, 13]. Importantly, it is expected that demonstrators can also point out important features that may vary from one experiment to another as the result of random processes, previously unknown equipment behaviour, and changes to the experimental procedure that students have accidentally introduced. The interaction the demonstrator has with the students and the experiment itself is depicted in Fig. 1. The interaction is direct and immediate, unlike past Internet-mediated laboratory experiments where no demonstrator was present (see Fig. 1).

As discussed by Florance and Lemckert [9], the World Wide Web has permitted students located away from the laboratory to operate real-time laboratory experiments remotely. Students can now conduct experiments on-line via a web interface based on the HyperText Mark-up Language (HTML) and utilising the 'frames' feature. In the case of Lemckert and Florance [14], this interface

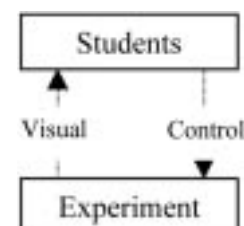


Fig. 2. Schematic of existing computer-aided learning package and real-time Internet-mediated practical class interactions. The dotted lines indicate computer link.

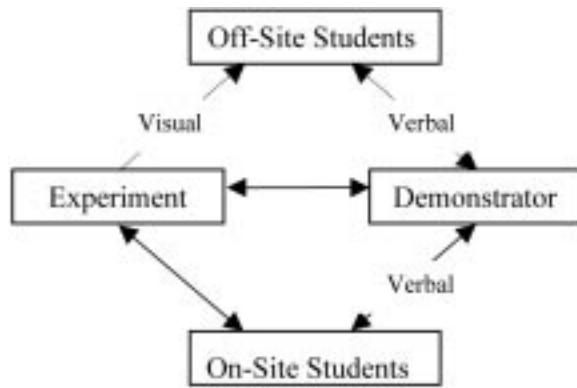


Fig. 3. Schematic of proposed new Internet-mediated laboratory experiment interactions that include off- and on-site students in the demonstrator-guided practical class. As in Figs. 1 and 2, the solid arrow lines indicate direct interactions, while the dotted lines indicate that the interactions go through an Internet link.

was designed to incorporate a series of support materials. These were accessible via appropriate linked images in a banner. They also proposed that experiencing laboratory practicals promised to address all of the aims of practical work, except for the development of manual skills (as per Table 1). It also promised to overcome some of the limitations of existing means of providing laboratory practicals to off-campus students. However, the use of on-line experiments was intended to supplement, rather than replace, other means of providing students with practical laboratory experiences.

The new form of delivery system developed as a result of this project incorporated a demonstrator into the existing RTMPC process (see Fig. 3). In this experiment, an on-site computer running Microsoft Windows 98 and equipped with Microsoft NetMeeting™, a streaming capable video

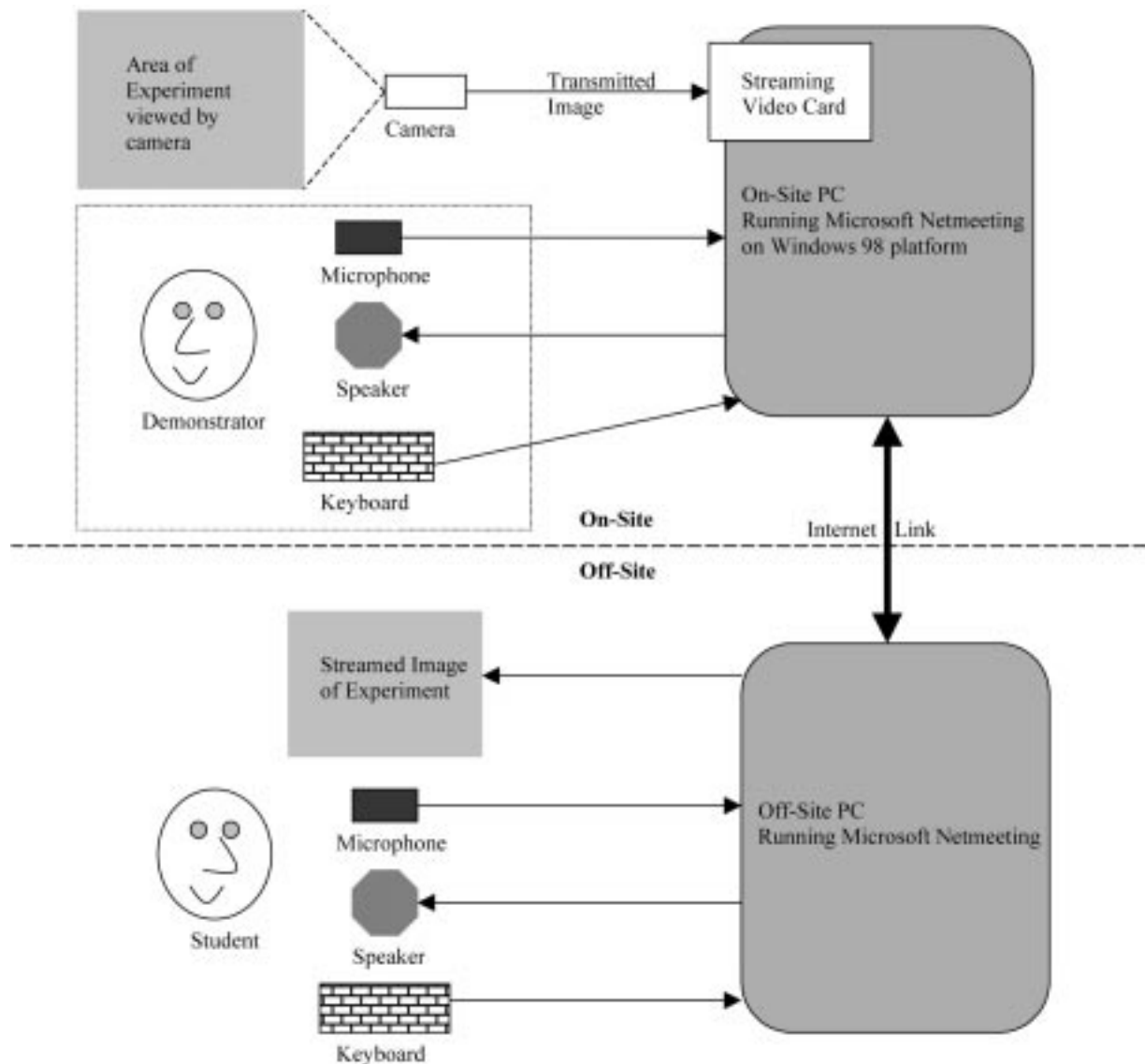


Fig. 4. Schematic of the newly developed Internet-mediated practical class delivery system that includes a demonstrator in the teaching/ learning system. The area surrounded by the dotted box indicates the demonstrator input that was previously not implemented.

card and a camera focused on the experiment, was used to transmit real-time video images of the experiment over the Internet. Students used Microsoft NetMeeting™ on an off-site computer to view the streamed images. The schematic of this arrangement is presented in Fig. 4. The use of Microsoft NetMeeting™ also permitted a two-way Internet-mediated voice link to be implemented between the demonstrator and the off-site students. This means that both on- and off-site students had similar opportunities to interact with the demonstrator. Significantly, the inclusion of the demonstrator into the teaching/learning process permitted students to ask questions and seek guidance when they most needed it (i.e., immediately).

THE CHOSEN TRIAL EXPERIMENT

The experimental arrangement chosen for this project was that of concrete beam testing. The primary aim of this concrete structure laboratory was to allow students to observe and understand two failure modes commonly encountered in practice (a schematic of the test rig used in the experiment is presented in Fig. 5). The beams are designed to fail either in shear or bending during testing. In terms of the experimental equipment, this is a high-cost activity that is not readily reproduced on different campuses. Reasons for this include the need for a suitable strong floor to support the testing rig and suitable (costly) hydraulic jacks must also be available. Therefore, this experiment, which should be considered essential in any structural engineering course, is ideally suited for the Internet-mediated approach.

In order to gain practical knowledge of concrete beams, students are typically required to undertake construction and testing of the beams and observe

the progressive cracking and mode of failure as load is applied. The students then analyse their recorded data, which includes loading levels, beam deflections, cracking characteristics and failure properties. As in the majority of practical activities, students write and submit a report on the outcomes of the experiment activity for assessment.

For on-site students, the laboratory takes place over four weeks, with weeks 1 to 2 involving the construction of the beam and week 3 the actual beam testing. Obviously, off-site students cannot be directly involved in the beam-forming process as this involves steel-frame construction and concrete pouring. To minimise this learning deficiency, support material must be supplied to the students before the beams are tested. Since the off-site students use an Internet-mediated delivery system, this support material follows a similar method (a website containing relevant information).

The on-site students are also required to set up the beam for testing using the steps outlined in Table 2. This procedure is conducted under the supervision of a lab technician and demonstrator to ensure safety and adherence to the correct procedures. This also shows on-site students how testing rigs are actually set up. As in the case of the beam-forming process, off-site students cannot be directly involved, so appropriate educational material must also be supplied.

As indicated in Table 2, the actual testing procedure involves loading of the beam at set increments and recording results. Some on-site students (who are assigned the recording task) listen to those students who read the gauges and then enter these results directly into their laboratory logbooks. With large classes, a number of students perform the recording task. This appears to result in a lack of interest among those students who are mostly observing and apparently gaining little from the experiment (see Fig. 6). In fact, some

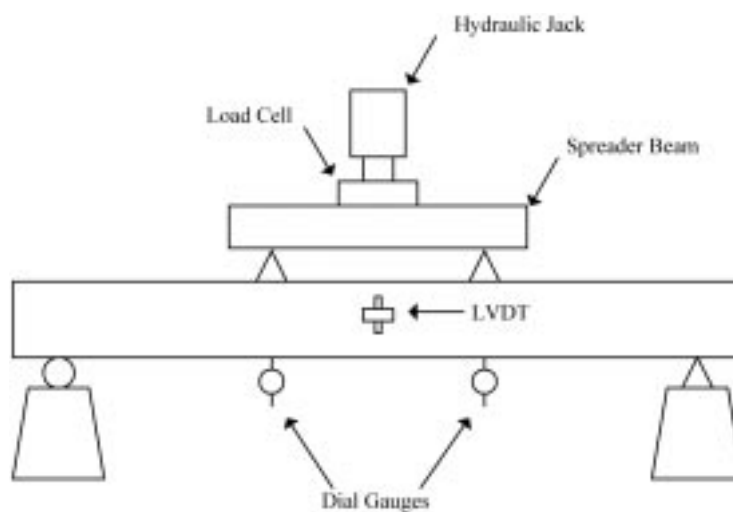


Fig. 5. Schematic of the concrete beam-testing arrangement. The LVDT (linear vertical displacement transducer) is positioned on the beam to record the displacement levels. In the present experimental trial, this information, along with the hydraulic jack loading and manual dial gauges, was supplied to the off-site students via the CHAT feature on Microsoft NetMeeting to ensure that the numbers were correctly recorded.

Table 2. Procedures used by the on- and off-site students

	On-Site Students	Off-Site Students
1	Strip beam from mould and take into the laboratory.	Work through web-based experimental set-up material
2	Place beam into position on the load stands.	
3	Paint the beam with whitewash—to assist in tracking crack propagation.	
4	Measure the support and load points and mark the beam.	
5	Set load points on top of the beam using cornice cement to ensure the points are level.	
6	Position the spreader beam across the load points.	
7	Position the load cell in the centre of the spreader beam.	
8	Solder the strain gauge meter to the strain gauge wires.	
9	Locate the dial gauges under the load points.	
10	Stick deflection gauge to the side of the beam at its centre.	
11	Connect the deflection gauge to the read-out.	
12	Record load, deflection and strain gauge readings at 5 KN load increment.	Record load, deflection and strain gauge readings at 5 KN load increment.
13	At each load increment, trace crack propagation with a crayon.	
14	Watch for failure load (maximum load) and deflection.	Watch for failure load (maximum load) and deflection.

students merely mill around the practical class. While the demonstrator can make every effort to involve them, resources and time can limit this involvement.

The off-site students recorded the deflection and loading data, in addition to viewing the cracking of the central region of the concrete beam via camera images streamed off-site using the Microsoft NetMeeting™ (see Fig. 7). The camera was fixed

at all times on the beam so that the students could view the cracking of the beam as marked by the on-site students (see Table 2, step 13). As a consequence of the fixed-camera arrangement, the view was a bit limited, but it still permitted viewing of the cracking process under investigation (which was a requirement of the learning activity). The students were able to interact with the demonstrator via both voice and text, the latter being



Fig. 6. Typical experiment arrangement and student activity. The concrete beam can be seen in the centre of the picture.



Fig. 7. Students conducting the experiment over the Internet. Note the microphone used for verbal communication.

achieved through the chatboard option. This was found to be necessary, as excessive noise within the laboratory sometimes prevented the off-site students from hearing the numbers being read out by the on-site students. To assist in this

interaction process, a student was asked to enter the numbers on computer (see Fig. 8), thus ensuring that accuracy was achieved and students were not disadvantaged. Future experiments should make use of analogue and/or digital meters, so



Fig. 8. Example of a student acting as an interface between the number readers and the off-site students.

that the loading and deflection information can be transmitted directly to the off-site students. This will then permit them to concentrate more on observations and give them more time to interact with the demonstrator.

VIEWS ON THE NEW EXPERIMENTAL METHOD

Student views on the new delivery system were sought before the experimental procedure was undertaken. Comments were obtained after the new delivery method had been described to the students, but before they had seen it. Student responses included:

- boring;
- a great idea;
- don't care;
- would be happy to sit at home, depending on distance;
- technically exciting; and
- good for high school students, as they can see what engineering is.

The responses represented a wide range of opinions and showed that, while some students thought the work seemed irrelevant to them, there was indeed the potential to enhance student education. This is not just limited to technical content but also to life experiences (as indicated by the last response).

Feedback, through open discussion, was also sought from the students who completed the practical class over the Internet. Their comments included:

- pretty smart;
- really train demonstrator (has to be an integrated component);
- groovy factor;
- good for people who do not want to come in;
- needs digital read-out link; and
- better outside (i.e., doing it hands-on), as you get the whole experience if you can get there.

Once again, a wide range of responses were received. However, students were very pleased with the newly developed Internet-mediated delivery method and felt that it had significant potential to enhance student learning. Importantly, the inclusion of the demonstrator helped the students gain knowledge of the experiment that was not

available from supporting written documentation. An example of this occurred when the students could overhear comments made by the demonstrator to the on-site students regarding aspects of the concrete cracking process. This therefore simulated a real presence for them.

PROJECT COSTS

Initial set-up costs of this new Internet-mediated delivery method were minimised, as the implemented system used existing software and hardware. Microsoft NetMeetingTM (which formed the interface between the experiment and the off-site students) was readily accessible and easy to use. The only high-cost items for this experiment, besides the actual experimental equipment itself and the computers, were the video card and camera. While we used a high-cost video streaming card, this was not essential, as a lower-cost unit would have been sufficient. Further, while other teleconferencing systems are available, the approach chosen here will prove significantly more cost-effective.

CONCLUSIONS

Recent advances in computer-based technologies have been applied to develop an Internet-mediated practical class that can be readily accessed by students located away from the experiment facility. Modern computer-based telecommunications enabled students to view and participate in a real-time interactive experiment. Importantly, the newly developed methodology permitted off-site students to interact directly with a real-life demonstrator.

Discussions with students about this novel approach to off-site practical class delivery showed a high level of support. This, of course, depends on the quality of the developed system, with care taken to ensure that the experiment was correctly designed (both educationally and practically), was suitable for such a delivery approach, had a suitably trained demonstrator and was technically robust. Overall, it was felt that the new approach has the advantages of other methods, with these benefits highlighted in Table 1.

REFERENCES

1. P. J. Mosterman, M. A. M. Dorlandt, J. O. Campbell, C. Burow, A. J. Brodersen and J. R. Bourne, Virtual engineering laboratories: design and experiments, *Engineering Education* (1994), pp. 279–285.
2. M. B. Kinze, V. A. Larsen, J. B. Burch and S. M. Baker, Frog dissection via the World-Wide Web: Implications for the widespread delivery of instruction, *ETR&D*, **44**(2) (1996), pp. 59–69.
3. N. S. Edward, Evaluation of computer based laboratory simulation, *Computers Educ.*, **1–3** (1996), pp. 123–130.

4. T. L. Veith, J. E. Kobza and C. P. Koelling, World Wide Web-based simulation, *Int. J. Engng Ed.*, **14**(5) (1998), pp. 316–321.
5. H. Higuchi, Multi-level, interactive web-based simulations to teach fluid mechanics and aerodynamics from middle school to college levels, *International Journal of Engineering Education*, online papers, sited 10/11/2001.
6. J. C. Waller and N. Foster, Training via the web: a virtual instrument, *Computers & Education*, **35**(2) (2001), pp. 161–167.
7. C. J., Lemckert, T. B. Martin and K. K. Wong, Remotely operated laboratory experiments in engineering for distance education students, *Proceedings of the 7th Annual Convention and Conference of the Australasian Association for Engineering Education*, Melbourne, Australia (1995), pp. 381–383.
8. C. J. Lemckert and J. R. Florance, Fluid laboratories the off-campus way: The flow project, *Proceedings of the Australian Association for Engineering Education*, 8th Annual Convention and Conference, University of New South Wales, Australia (1996), pp. 230–234.
9. J. R. Florance and C. J. Lemckert, Extending real-time, web-mediated laboratory practicals, in A. Ellis (ed.), *Access Through Open Learning*, Southern Queensland University Press (1997), pp. 1–9.
10. Ewald and Page, 2000.
11. C. J. Lemckert and J. R. Florance, Real-time Internet mediated laboratory experiments for distance education students, *British Journal of Educational Technology*, **33**(1) (2002), pp. 99–102.
12. Hedley and Barry, Maximising learning of electronic laboratory skills, *Proceedings of the Australian Association for Engineering Education*, 9th Annual Convention and Conference, University of New South Wales, Australia, CD-ROM (1997).
13. U. Nuldon, Designing environments for reflection and collaborative learning, *Proceedings of the Australian Association for Engineering Education*, 9th Annual Convention and Conference, University of New South Wales, Australia, CD-ROM (1997).
14. C. J. Lemckert and J. R. Florance, Considerations in the design of real-time Internet mediated laboratory experiments, *Proceedings of the 1st Asia-Pacific Forum on Engineering and Technology Education*, USICEE, Monash University, Melbourne, Australia (1997), pp. 303–306.