Laboratory demonstrators' perceptions of the remote laboratory implementation of a fluid mechanics laboratory

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Abstract: *Remote laboratories are a mature technology that is becoming increasingly prevalent in the delivery of undergraduate engineering degree programs. Acceptance by teaching staff is important in order for remote laboratories to gain widespread support, however existing efforts have overlooked the perspective of the demonstrators who supervise the laboratory classes. This paper investigates the responses of five laboratory demonstrators to the conversion of a fluid mechanics laboratory to the online mode of delivery. The demonstrators' responses were largely positive towards the shift to remote access, with a clear feeling that the online mode would be better for them as demonstrators. The demonstrators did express concerns, however, that the learning experience of their students could be compromised by the alternative access mode.*

Introduction

Laboratory classes are an essential part of the education of undergraduate engineers. Laboratories provide the opportunity to acquire a range of skills and knowledge that are not available through other avenues (Feisel & Rosa, 2005). Providing these opportunities can be very expensive in terms of equipment and consumable costs, as well as the time and energy of academic staff required to prepare, supervise and assess these laboratories. As the size of engineering cohorts has grown (King, 2008), providing laboratory experiences to all students has become more challenging in terms of cost, space and scheduling.

One alternative solution is to provide remote access to laboratory hardware. Remote access to the hardware can relax many of the constraints of the in-person experience – scheduling, supervision and directness of control can all be achieved much more easily when students can connect remotely.

Remote laboratories first become prevalent in the mid 1990s (eg (Aktan, Bohus, Crowl, & Shor, 1996), and since then remote laboratories have become a relatively mature technology. The field has developed to the point where the literature contains reviews of remote laboratories (Ma & Nickerson, 2006), and the challenges have moved from technical implementation through to pedagogical design and frameworks for inter-institutional sharing of equipment. Research into the learning effectiveness of remote laboratories shows that the perceptions of the students towards the laboratory are significant (Lindsay & Good, 2005); the perceptions of teaching staff have not been well explored.

Curtin University is part of the LabShare consortium (www.labshare.edu.au), an Australian government funded initiative to build a shared network of remote laboratories across five Australian universities. An important part of the development of LabShare, and of the spread of remote laboratory classes in general, is the acceptance of the staff who teach the courses in which these laboratories are used. While the technical implementation can continue, unless the teaching staff can be convinced to adopt remote laboratories, they will remain only a novelty. There have been a number of initiatives intended to convince academics of the value of remote laboratories; however to date the laboratory demonstrators have been largely overlooked.

Many face-to-face laboratory classes are in fact demonstrated by someone other than the lecturer for the subject; often postgraduate students are placed in the role of supervising students in the laboratory. While it is unlikely that the demonstrators will be the ones making the decision about the move to a remote laboratory mode, it is the demonstrators who will be called upon to present this mode to the students. The demonstrators' attitudes towards the remote access mode have the capacity to prejudice the students' experiences; as such it is essential to determine the demonstrators' perceptions of the remote access mode. This paper captures the responses of a group of laboratory demonstrators to the online conversion of a fluid mechanics laboratory at Curtin University.

The Experimental setup

The *flow through pipes* laboratory is part of the second-year Fluid Mechanics 230 unit at Curtin University. This experiment allows students to explore how fluids act in different flow regimes (laminar, turbulent and transition), and to compare experimental measurements with the theoretically predicted model.

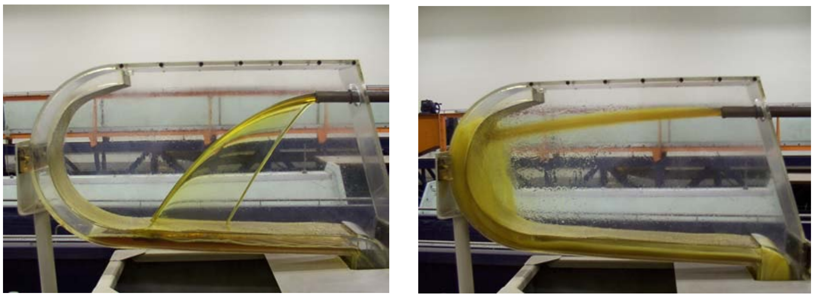
For last two decades the flow through pipes laboratory experiment was conducted using a large experimental rig featuring a 6.1m long central pipe – the "big rig" (Fig 1a). In early 2010 the mercury manometers used to measure pressure in the pipes began to leak, making the rig unsafe for use by students. This saw the introduction of a small laminar-turbulent flow experiment setup this year, which became known as the "small rig" (Fig 1b). At the same time, work is underway to build a remotely accessible version of the experiment for integration into the LabShare network; this version of the experiment is known as the "remote rig" or the "online rig". Therefore, three experimental setups are used for this study: laboratory hands-on version big rig, laboratory hands-on version small rig, and remote lab (online) version.

(a) (b)

Fig. 1. Laboratory equipment of flow through pipe – (a) Big rig; (b) small rig

The Laboratory– Big rig version

The big rig (Fig 1a) consists of a 6.1m long pipe brass pipe through which oil is continuously circulated by a hydraulic pump. The pipe has nineteen piezometric tappings that are each connected to a mercury-filled manometer to measure the pressure at specified locations along the pipe. The flow in the pipe can be maintained laminar up to a Reynolds Number (Re) of about 2000. Turbulence is initiated by inserting a rod at the upstream end of the pipe; the flow can becomes turbulent at a Re of about 5000. The pipe discharges into a transparent perspex catchment so that the difference between laminar and turbulent flow can be visually observed (Fig 2)



(a) (b)

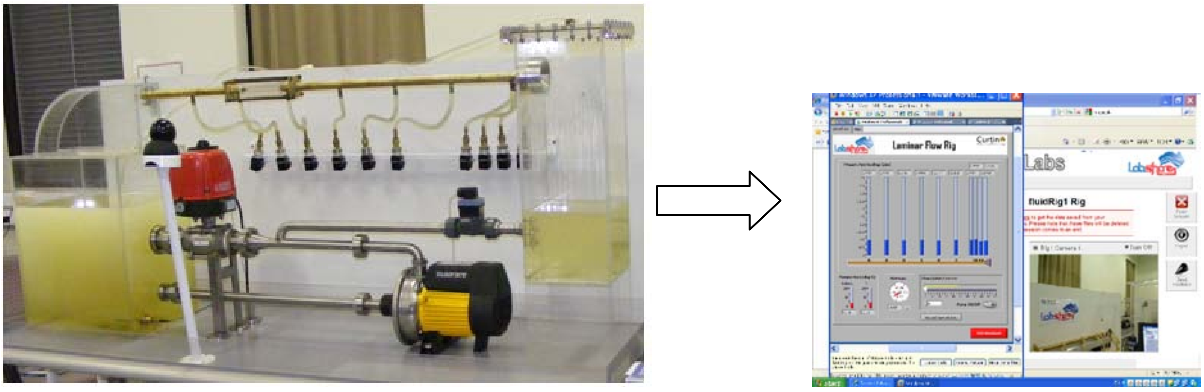
Fig 2. Typical laminar flow (a) and turbulent flow (b) - Big rig

The Laboratory - Small rig version

The small rig is a small horizontal pipe of nominal diameter 3 mm. Figure 1b shows the arrangement in which water from a supply tank is led through a flexible hose to the bell-mouthed entrance to a straight pipe, along which the frictional loss will be measured. Piezometer tappings exist at an upstream section which lies approximately 135mm away from the pipe entrance, and at a downstream section which lies approximately 120mm away from the pipe exit. These clear lengths upstream and downstream of the test section are required to prevent the results from being affected by disturbances near the entrance and exit of the pipe. The length between piezometer tappings is 524mm. The piezometer tappings are connected to an inverted U-tube manometer, which reads the differential pressure. The rate of flow along the pipe is measured by timing the collection of water in a measuring cylinder.

The Laboratory - Online version

The online rig (Fig 3a) consists of a 1.5m long brass pipe with internal diameter 19mm. The pipe has ten tappings that are each connected to digital pressure gauges to measure the pressure at specified locations along the pipe. Oil is continuously circulated through the pipe by a hydraulic pump. The pipe discharges the flow into a transparent chamber and the flow profiles (laminar or turbulent flow) can be visually observed using high definition web cameras. In addition the cross sectional flow profile can be observed using laser sensors. The flow in the pipe is controlled using an automated valve, which directs the oil either to the pressure pipe, or discharges it back to the holding tank.



(a) (b)

Fig. 3. Online version rig and online window

The control interface was developed using labview, with the remote access and scheduling implemented using the LabShare Sahara software (Labshare, 2010). All of the control valves and pump flow rates can be controlled remotely, and required data such as pressure, temperatures and flow velocity can be recorded in the remote computer. As the whole system is connected to the internet, anyone who is eligible to log in to the system online can run the experiment; control the flow through the rig and observe the flow profile in own computer screen. Also all measurement data can be recorded online. Groups of students can log in to the system from different locations and handle the experiment as group work.

Laboratory demonstrator selection & training

Usually three to five postgraduate students are selected from Civil, Chemical or Mechanical Engineering based on their availability. These three departments are considered because this lab is combined together only for these engineering departments. The demonstrators are chosen on their experience, expertise and enthusiasm for fluid mechanics. The academic responsible for the subject meets with each of the demonstrators who are willing to take this role and checks their past experiences. Each of the demonstrators is supplied with the laboratory briefing sheet well ahead of the laboratory session starts.

At least two weeks before the real laboratory sessions, a trial experiment is run with the demonstrators performing the role of the student. They are required to take the data of their own and have their calculations checked by the academic. In this way they are familiarised with the student perspective of the experiment, and of the skills necessary for the laboratory. This demonstration forms part of a wider briefing, where the full laboratory activities, safety issues as well as assessment procedures are explained by the academic. In order to ensure the uniform marking among the demonstrators, each of them is supplied by a marking scheme and a short briefing lecture is given by the respective academic for lab report marking.

In 2010, five demonstrators from engineering faculty postgraduate students were selected for Fluid Mechanics lab, four from Civil Engineering and one from Chemical Engineering. Two were new demonstrators for 2010, and as such had only been demonstrators for laboratories using the small rig; three were return demonstrators, who had taught on the big rig in 2009, and then on the small rig in 2010. All five demonstrators attended the "Improving Teaching & Learning in Laboratories" Laboratory Demonstrators' Workshop organized by Faculty of Science and Engineering. This workshop is a requirement for all sessional staff teaching in laboratories in the Faculty. In this workshop, participants discuss and generate solutions to common teaching & learning problems, gain a better understanding of how students learn sciences, learn how to provide effective feedback and gain knowledge about the overall aims and objectives of the laboratory classes.

Gathering the Demonstrators' Perceptions

In order to get clear perceptions from the demonstrators on remote laboratory conversion, two demonstration sessions were organised. First, a big rig trial demonstration was conducted for the two demonstrators who had not previously taught on that rig. This was done to provide uniform knowledge to all the demonstrators on hands-on rigs. Secondly, a demonstration was conducted with online rig for all the demonstrators to understand the basic differences between hands-on rig and remote-rig.

After participating in the two demonstrations, the laboratory demonstrators were asked to present their views on eleven topics during a two hour brainstorming session. The topics represent and cover a range of relevant factors related to the learning outcomes of the unit:

1. Student's active participation
2. Visualization of flow pattern
3. Controlling the equipment
4. Measurement errors
5. Team work
6. Repetition of measurements
7. Sensory experiences

8. Accidental events (such as, the lab was shut down due to the high mercury vapour)

9. Laboratory learning process

10. Demonstrating the overall lab

11. Safety issues

All five demonstrators participated, each providing a response to each of the eleven topics, as well as some open form "Any other comments?" responses.

The demonstrators' responses

Individual responses were gathered and responses for each criterion were analysed for all the respondents. Overall, the responses were on the whole positive towards the idea of remote laboratories. The five demonstrators were fairly consistent in their responses, however there were specific instances where opinions varied. This section reports on the demonstrators' responses to each question in turn, illustrated with direct quotations from the survey responses where appropriate.

1. Student's active participation

The responses were mostly in agreement that the students would be more active in the big rig mode. The reasons for this response varied, however. One demonstrator felt that the lack of distractions in the laboratory would promote focus - "when they will attend the lab they have no other business to do except lab work." Another emphasised the physical size of the rig – with a 6 metre rig, you need multiple students actively working together, but on a computer screen interface you do not.

2. Visualization of flow pattern

The responses were mostly in agreement that the flow pattern could be visualised in both modes, however they all agreed on the proviso that this would require good cameras and a good network connection. One demonstrator expected that this connection would not be adequate; another disagreed, suggesting that the "flow pattern can be seen and felt in both cases".

3. Controlling the equipment

The demonstrators were unanimous in their agreement that it would be easier to control the equipment using the online interface. One demonstrator did qualify this response by returning to the theme raised by his colleague to question one – that the students may be distracted by doing other things "such as chatting with friends".

4. Measurement errors

This question was intended to deal with the concept of variation in results, which is a standard and important part of any experimental work. The responses were all in agreement that the measurements taken with digital instruments were more likely to be accurate than those taken with the naked eye. One demonstrator, however, interpreted the question as dealing with problems with measurements, rather than the inherent variability – mistakes rather than errors. From this perspective, the online approach was considered inferior, because it would be harder both to diagnose and to remedy problems as they arose – "measurement errors may not be solved if is due to problems with instrument".

5. Team work

The responses to this question showed an interesting perspective from the laboratory demonstrators. The responses were certainly in agreement with the well-held concern that the in-laboratory interactions between students will be lost in the shift to the online mode. Some of the responses, however, suggested that it would be replaced with an online-form of teamwork: "A new form of team work … may emerge for lab work session."

The theme of the nature of the hardware also manifested in this question – "In order to get the successful set of reading, teamwork is more important". This response again relates to the size of the big rig, in which multiple operators are physically necessary to capture all the data.

One demonstrator also noted that in the online approach all students will have to operate the equipment, with no opportunity to be a passenger in a team.

6. Repetition of measurements

There was unanimous agreement that the online mode would better support the repetition of measurements. One demonstrator suggested that the online mode would also help eliminate transcription errors between students, as the data would be copied directly and correctly in electronic format.

7. Sensory experiences

All of the demonstrators responded to say that that students will miss out on sensory experiences, with most of them going further to explicitly indicate that this will be a problem.

8. Accidental events (such as, the lab was shut down due to the high mercury vapour)

Many of the responses referred to the possibility of failure for the remote laboratories, however the focus was in the telecommunications infrastructure, rather than the hardware itself. Remote rigs fail due to internet connections being down; in-person laboratories fail due problems with the rigs themselves. This is possibly a bias introduced through the training by the model of having multiple redundant copies of each rig in the remote laboratory pool; however it is a shift in their concept of reliability. There were also some responses that confounded safety with these kind of unexpected events.

9. Laboratory learning process

While one of the demonstrators was quite clear in the equivalence of the two formats – "students will equally learns both in hands on and online versions" – the majority response was that there would be changes in the learning. What was noteworthy was that these responses appeared to focus more on the learning process, rather than the learning outcomes. There were specific concerns such as the data being plotted for them, rather than students doing it for themselves, as well as the general concern that "they may not have laboratory experience".

10. Demonstrating the overall lab

The overall theme was that the online mode would save time for both students and demonstrators. It was clear that they had embraced the hybrid mode of delivery suggested in the training session, and that they saw it's potential, however the responses still emphasised the importance of the demonstrator being able to provide feedback to the students.

11. Safety issues

There was unanimous agreement that the online delivery was safer, however there was a concern that the students may take this safety for granted – "the student will miss experience of importance of safety issues in real life environment".

It is also significant to note that one demonstrator added an additional, unprompted, response:

"Finally, remote version is suitable for those who know about the features of the instruments and have the idea what it is going to present. For the first time user it may prove hard to guess without observing physically. Hand on version suits for them and they can try remote version for later works or research."

This response shows that the demonstrator is considering a different model of accessing the laboratory; that the in-person mode is for familiarisation with the equipment, whereas the remote mode is suitable for follow-up data capture and analysis.

Discussion

Overall, the tone of the responses was positive towards the change to the online mode, however there were some reservations expressed by the demonstrators. There was an overall sense of uncertainty regarding the nature of the online experience. While this can be partially explained by a lack of familiarity – the demonstrators were being trained for this online mode in the future, and had not actually experienced the laboratory class in this mode – there are also some other themes that emerged to support these concerns.

The first of these themes was the presence of distractions outside the laboratory. Students in a face-to-face laboratory are in the laboratory for the sole purpose of completing an experiment; students controlling equipment via computer from home are not. The potential for distractions in the online mode is greatly increased; multiple demonstrators expressed their concerns regarding this possibility.

The second theme to emerge was the nature of the equipment itself. The existing big rig is six metres long, and it is physically impossible for a single person to operate all the controls and read all the measurements at the one time. Multiple operators are required, and they are required to communicate as a team to make the experiment work. The shift to an online version makes the rig controllable from a single computer screen, making it possible for a single user to operate the rig unassisted. It was clear that the demonstrators felt that this change would result in some kind of loss to the students, however the exact nature of this loss was not clearly articulated.

The role of the demonstrator was also highlighted by the responses – it was (unsurprisingly) clear that they felt the demonstrator was a key part of the experience. The ability to answer student questions, provide feedback and to address potential problems with the equipment were all included in responses. Interestingly, the responses suggested that they felt that there would still be a role for demonstrators in the online mode of delivery; it was just not clear how they saw that role being implemented.

Overall, the demonstrators were positive towards the idea of a shift towards the online mode of delivery. From their perspective of demonstrators, they were universally supportive of the online mode, which they saw as easier to control, and more likely to produce accurate data. The concerns raised by the demonstrators were more expressed on behalf of the students – that the changed nature of the online experience would in some way disadvantage their learning. The demonstrators see that the online mode is different; they are unsure that this different approach is as good for students.

Fortunately, most of the concerns raised by the demonstrators are issues that were already under consideration in the design of the remote access experience, and are already well-represented in the literature on student learning in remote laboratories. A well-integrated curriculum that integrates well-designed remote laboratories can address the deficiencies of any particular learning experience by ensuring balance across the other learning activities; this is the intended context in which this remote laboratory will operate.

Conclusions

Laboratory demonstrators are an essential part of the laboratory learning experience; however until now they have largely been overlooked in the development of remote laboratories. This study has investigated the attitude of five demonstrators towards the conversion of a fluid mechanics laboratory class from the in-person mode to the remote-access mode.

The responses of the demonstrators show that they believe that the online mode will be better for them as demonstrators, but that they have reservations regarding some aspects of the students' learning. They see the nature of the laboratory experience changing, and they have concerns about whether it is good for students.

The concerns of the demonstrators match those of the academics developing the laboratory experiments, and as such they are being addressed by the design of the learning activities. This study, however, highlights the importance of making the demonstrators aware of these design activities, so that their issues can be properly addressed, and that they can manifest their support of remote laboratories without their concerns for the students' learning outcomes.

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