Use of web-conferencing software to enhance practical learning for distance students in a first-year Engineering course

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Structured abstract

BACKGROUND
For many years, Deakin University has delivered an accredited undergraduate engineering course by means of distance education. One of the chief challenges is to provide the necessary practical instruction and experience in engineering to these students. In first-year physics and first-year materials science, off-campus students normally attend on-campus lab classes either on a Saturday or as part of a residential school. However, because some students live either interstate or overseas, it is sometimes impossible for small groups of students to attend an on-campus lab class.

PURPOSE
This paper investigates whether web-conferencing software can be an effective means for delivering practical classes to small groups of distance students in first-year physics and also first-year materials.

METHOD
Over three semesters in 2012, we employed the *Elluminate-Live!* software platform to broadcast six lab practicals in first-year physics, and one practical in first-year materials engineering. The students submitted practical reports as did all the other students in each unit. The students in each unit fell into three groups: on-campus students, off-campus students who performed their practicals on-campus, and off-campus students who performed their practicals "virtually" via an *Elluminate-Live!* session.

RESULTS
The trials showed that it is possible to broadcast both physics and materials practical classes by means of web-conferencing software. Report marks of the students performing practicals by this method were comparable to those in the other groups.

CONCLUSIONS
Our experience with four initial trials in delivering practical classes over the Internet was encouraging, and showed that the concept will work if done in an effective way.

KEY WORDS
Distance education, off-campus laboratories

Introduction

Distance education has become an accepted means of providing tertiary education and training to increasing numbers of students who find it difficult or impossible to attend the more conventional on-campus classes (Cleveland-Innes & Garrison 2010). Distance education in undergraduate engineering is offered by a number of Australian universities. Some institutions offer a limited number of subjects this way, while others offer complete accredited bachelor's degrees. For the past 20 years, Deakin University has taught a fully-accredited Bachelor-of-Engineering course, with current specialisations in civil, mechanical, electrical/electronics, and mechatronics/robotics (Long, 2004).

For the distance-education provider, perhaps the most challenging task is teaching laboratory practicals (Walkington 1994; Anastasiadis, 2006; Krute 2012). Engineering students require practical training to link their theoretical training with the real world, and to give them valuable experience in performing many of the hands-on tasks that engineers routinely perform.

The simplest and most effective way to provide direct practical education to distance students is to run lab or practical classes at times out of normal office hours. This is often conducted on a Saturday or in the evenings. This is the current approach we take for delivering practical education to students studying first-year physics and first-year materials (Long, 2012b). Other distance-education providers follow a similar approach (Keleher, 2011; Woolnough, 2006). While this may work for the majority of off-campus students, there is always a small number in each cohort that finds it very difficult to impossible to travel to the home campus for lab classes. Such students may reside interstate, overseas, in remote locations, or even on a ship at sea. We have experienced students in each of these situations.

Delivering practical education to these students is indeed quite a challenge (Hall, 2006). Other solutions to this problem vary from subject to subject, but they include providing students with a video of a lecturer performing a practical (Abdel-Salam, 2012), students performing computer simulations in lieu of hands-on practicals (Joordens, 1998; Margalef, 2007; Parush, 2002), providing students with experimental kits so that they can perform their experiments at home (Jones, 2003; Hendricks, 2009; Long, 2012a), and offering remotely-controlled practicals via the Internet (Azad, 2012; Lindsay, 2005; Lowe 2013). Accreditation requirements may, however, restrict some of these solutions (Palmer, 2005).

In recent years, Deakin has sought to use modern communications tools to enhance teaching, both for on-campus and off-campus students. One recent tool is web-conferencing software, which allows multiple users to communicate at once in real time. Such tools include instant messaging, *Skype*, *WebEx*, *Adobe Connect Pro*, *Yugma*, *Elluminate!*, and many others. Since 2009, we have been using the *Elluminate-Live!* software platform to deliver tutorials in physics, engineering materials, and mechanical engineering to off-campus students, allowing for the first time the effective delivery of a simultaneous "in-class" experience to a group of students who are scattered around the country or overseas. Extending our success in delivering tutorials by means of web-conferencing, this study examines whether the same platform may be used to deliver practical classes to off-campus students. We performed trials in two units: SEP101, Engineering Physics; and SEM111, Engineering Materials-1.

SEP101 Engineering Physics and SEM111 Engineering Materials

All first-year engineering students at Deakin University enrol in both SEP101 (physics, Long 2013) and SEM111 (materials). In 2012, SEP101 had six practical exercises (table 1), and SEM111 had one. All on-campus lab classes took about three hours each. In SEP101, an on-campus student performed the experiment, wrote out a basic report, and submitted their work on the day for marking. Reports were marked out of top score of 10 points. The conduct of the lab practicals was essentially the same as in our previous work. The only change from previous years (Long, 2012b) was the dropping of electrical experiments and the addition of two experiments on springs and standing waves.

Table 1: Lab experiments assigned in first-year engineering physics.

Experiment	Activity
1	Introduction to Microsoft Excel
2	The simple pendulum and measurement uncertainties
3	Rotational inertia of a flywheel
4	Viscosity of a fluid
5	Springs and Hooke's law
6	Standing waves on a wire

In SEM111, all students performed one experiment: measuring the electrical resistance of three different metals as a function of temperature over the range 0–100 °C (figure 1). For each metal, they then determined the electrical resistivity, and the temperature coefficient of resistivity. The test samples were wires: steel, copper, and constantan. After completing the experiment, the students wrote standard reports and submitted them for assessment. The reports were marked against a four-level rubric, and the maximum possible score was 24 points.

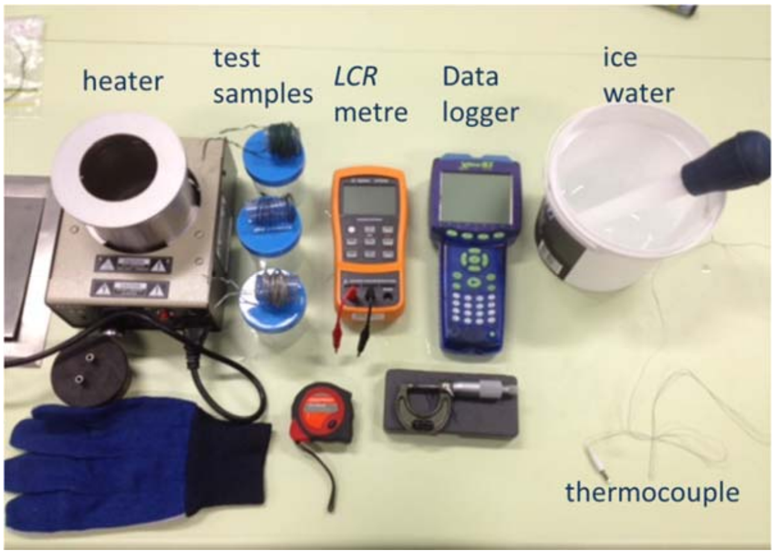

Figure 1: Materials for the SEM111 practical on electrical resistivity of metal wires.

Elluminate Live! Software

The web-conferencing software *Elluminate-Live!* (*E-live*) is becoming increasingly popular with educational institutions for running Internet-based classes (Elluminate Live! 2009; Chaturvedi, 2011; Page, 2011) We are using it in a number of subjects across engineering, including physics and materials. Once a session has been booked, a unique web address is created for a given session. Students are given the address prior to the session, and then log in at the start time. During a session, a number of key teaching elements are available to the tutor and students (Figure 2):

- Voice and video transmission, similar to Skype.
- A “whiteboard” that allows multiple means of displaying pictures, Power-Point slides, text, and hand-writing,
- A chat area where written messages may be transmitted among the class,
- A list of participants and various signals to attract attention or indicate simple yes-no messages,
- The ability to share another application or program from the tutor’s computer with the rest of the class,
- A session-recording feature, so that students may re-play the session for review,
- The session may remain active after the formal tutorial finishes, so that students may talk to each other and study together – a “virtual study room”.

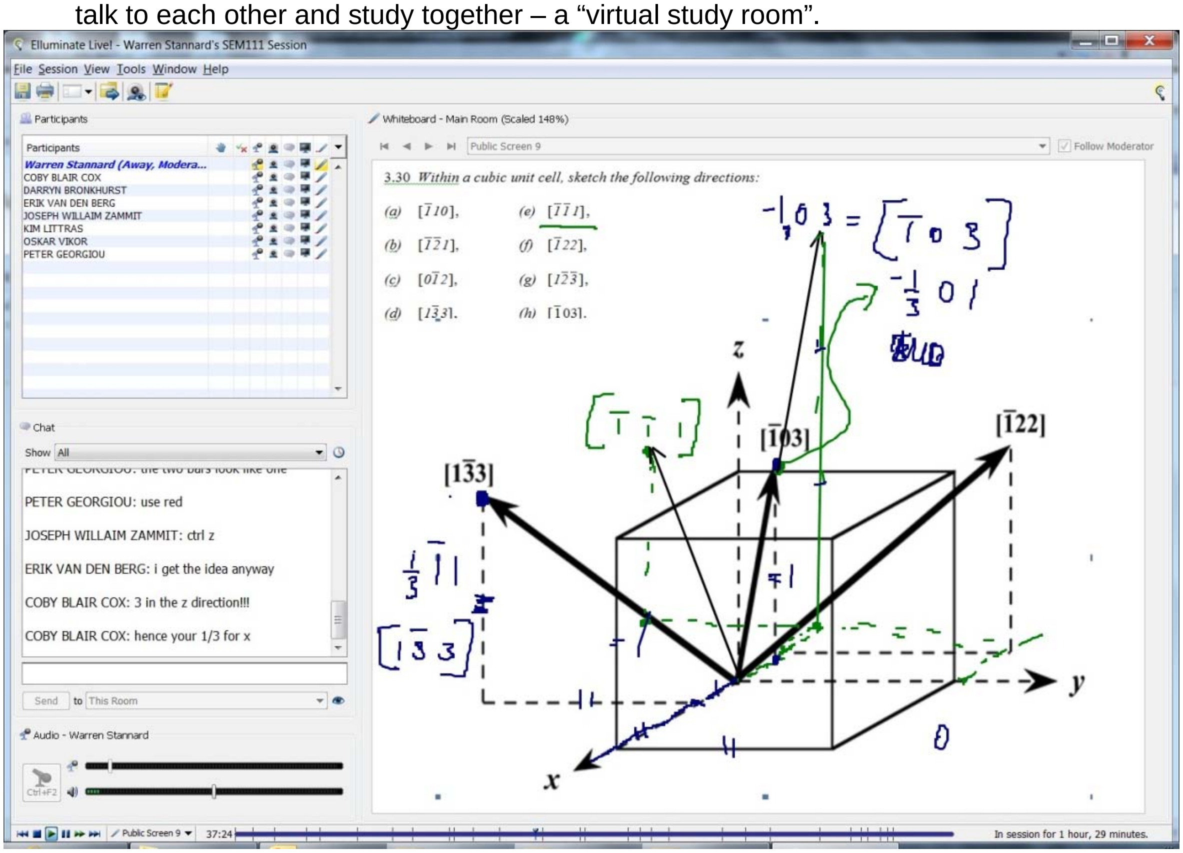

Figure 2: *E-live* being used in a materials tutorial for off-campus students.

Method

Standard tools for web-casting the practical sessions were employed:

1. a USB-headset with microphone
2. a Wacom-Bamboo tablet mouse
3. a high-quality webcam

Each experiment was set up near the broadcasting computer. The webcam (on a wide-field view) was fixed in place on a retort and pointed toward the apparatus and an adjacent whiteboard. The practical sessions were conducted by one or two demonstrators. In the case of two demonstrators, one sat at the computer and did most of the talking, and the other operated the experimental gear (Figure 3). The original goal was for the demonstrators to guide the students through the experiment, taking instructions from the students. It was intended that the students would be able to take their own instrument readings and measurements from the images collected by the video feed.

The physics experiments were delivered twice, once in semester one and again in the summer semester. The materials experiment was also delivered twice, once in the second semester and once again in the summer. During semesters one and two, both subjects had on-campus as well as off-campus cohorts. The summer-semester offerings were distance-ed. only. The majority of off-campus students performed their experiments at on-campus lab sessions. As intended, only a small number of students performed the experiments via *E-live*. The physics practicals required two *E-live* sessions, whereas the materials practical required only one. Each individual session was three hours long.

Figure 3: Authors performing the fluid viscosity experiment via *E-live* The first demonstrator is about to drop a small steel ball into a cylinder of glycerine.
The second demonstrator measures the fall time with a stopwatch.

Once the teaching periods had ended, the lecturer contacted the students who attended the *E-live* practical classes to ask for their feedback. He asked four simple questions:

1. In the Engineering School's delivery of practicals via *E-live*, what worked well?
2. What did not work so well?
3. What needs to be improved or could be improved?
4. Should the School continue to offer practicals to off-campus students in this manner, especially when students live interstate or overseas?

Results

Figure 4 shows an example screen-shot from one of the *E-live* sessions. While it was intended that students collect their own data by watching the video feed, we found that the video resolution and transmission speed was inadequate for this task. Thus it was generally not possible for students to read measuring devices such as stopwatches and rulers. Moving objects, such as a pendulum or a mass oscillating on a spring, produced delayed, jerky motions as viewed remotely. Students even found taking readings from digital devices difficult (Figure 5). The instructors found that in performing the experiment “Standing waves on a wire,” the students were unable to see the vibrating wire at all (Figure 6). However, the students could hear the resonance in the wire if the microphone was held nearby. In this case the instructors discussed the experiment in general, then provided the students with the necessary data. The physics exercise on Microsoft Excel did not require much session time. The demonstrator described the exercise and left students to complete it in their own time.

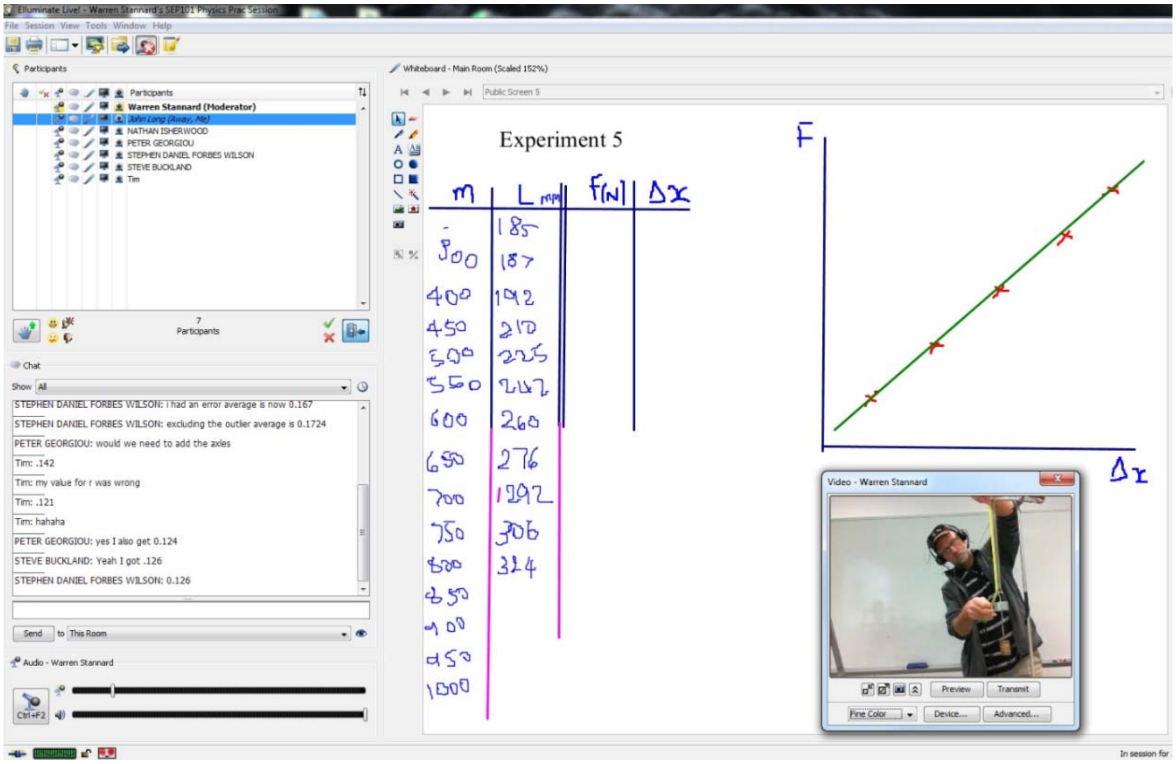

Figure 4: Physics practical “Springs and Hooke’s law” being delivered by *E-live.*

Figure 5: Reading an *LCR* (inductance-capacitance-resistance) metre during the materials practical.

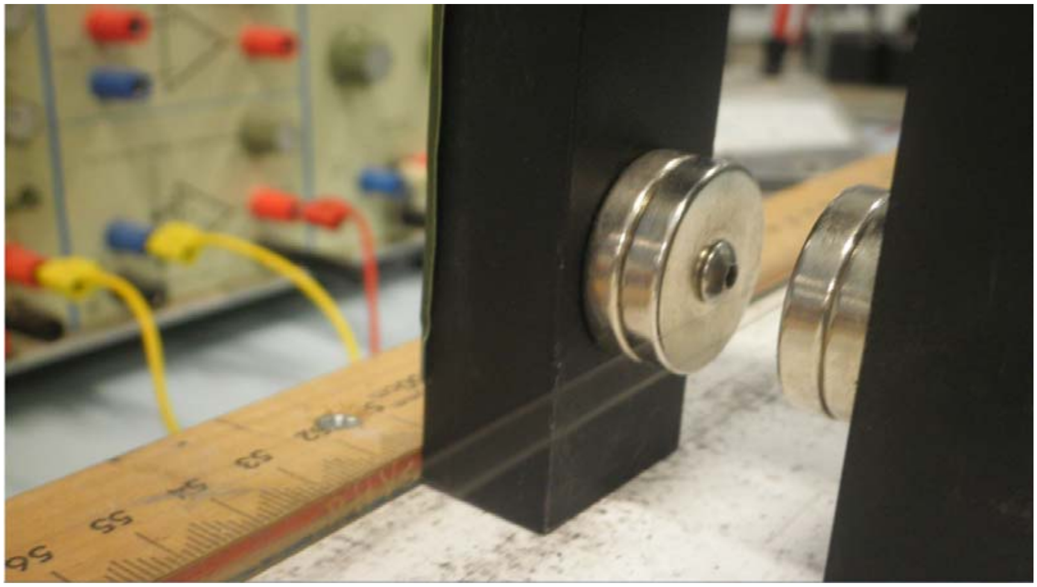

Figure 6: Standing-waves practical. A wire vibrates as a sinusoidal current is passed between the poles of a magnet. The standing waves are difficult to see even in a still photograph.

Thus the instructors were required to lead the students through the experiments. Numerical data was written down on either the whiteboard area of the *E-live* screen or on a physical whiteboard in the view of the camera. Throughout the sessions students had the opportunity to ask questions and pass messages to each other via the chat utility. All practical sessions were recorded so that students could review the proceedings as they wrote their reports.

Table 2 compares the academic performance of the physics students who attended the *E-live* practical classes with the remaining students who performed the same experiments hands-on. In semester one, all four students who attended the *E-live* practicals submitted reports. In summer, an additional three students attended the *E-live* practicals but did not submit reports. The students who attended the *E-live* physics practicals and submitted reports, on average, obtained higher marks than the other two groups of students.

Table 2: Average report marks for the students in physics.

Semester - 2012	Total on-campus assessed	Total off-campus hands-on assessed	Total off-campus *E-Live* assessed	Avg. marks/10 on-campus	Avg. marks/10 off-campus hands-on	Avg. marks/10 off-campus *E-live*
One	139	37	4	6.7	6.8	8.2
Summer	0	14	10	-	6.4	6.9
Overall	139	51	14	6.7	6.6	7.1

For the materials unit, the comparative student performance is given in table 3. In semester two, two students who attended the *E-live* session did not submit a report. In summer, the corresponding number was three. Again, on average, the report marks for students who attended the *E-live* session were higher than those of the other two groups.

Table 3: Average report marks for the students in materials.

Semester -2012	Total on-campus	Total off-campus	Total off-campus *E-*	Avg. marks/24	Avg. marks/24	Avg. marks/24

	assessed	hands-on assessed	*Live* assessed	on-campus	off-campus hands-on	off-campus *E-live*
Two	115	25	12	17	20	20
Summer	0	16	8	-	17	20
Overall	115	41	20	17	19	20

In general, the feedback from the four *E-live* students who responded to the questionnaire was positive. The students were very happy that the School offered the lab classes in this manner. The main thing they mentioned needing improvement was the quality of the video. All students were grateful that it was not necessary to travel to Geelong from interstate to perform the practicals.

Discussion

In this preliminary study, we have demonstrated that it is possible to "web-cast" a real practical to a group of off-campus students. (This is in contrast to Chaturvedi and colleagues (2011), who employed *E-live* to deliver a class that *simulated* a practical.) To our knowledge, this is the first time web-conferencing has been used in Australia to deliver engineering lab practicals to off-campus students. Although the number of students in the trials was very small, this is to be expected. We stress that it is educationally preferable for students to perform the experiments hands-on. Where this is not feasible, taking a small group of students "virtually" through an experiment is a possible alternative. As far as report marks are concerned, our results suggest that remote students are not at a disadvantage, compared to the students who perform the experiments hands-on. This is consistent with the work of Abdel-Salem (2012), who found similar results when students viewed a video of a practical, then submitted a corresponding report.

We have learned a number of important lessons in this work to help us with future offerings of practicals by means of *E-live.* The delivery had three key limitations:

- It was difficult to show the lab apparatus and instruments in detail, especially since the webcam was fixed in place.
- Students were not really able to collect their own data as the experiments progressed. The demonstrators were required to write the data down on the whiteboard.
- Issues related to Internet band-width, video-resolution (640 × 480 pixels maximum), and download times in the transmission itself reduced the quality of what the students actually saw. Voice and sound, however, were generally not a problem.

We also learned that:

- It is best to employ two presenters for each session;
- The physics practicals are best presented in two short sessions rather than one long session;
- A high-quality web camera is necessary. Zoom capability would be a significant help;
- There are limitations in the video quality due to the video resolution available in the software;
- A wireless speaker/microphone headset is desirable;
- Students need encouragement to participate in the session rather than merely watching;
- At least one student attended both an on-campus session and the corresponding *E-live* session. The reason was to reinforce what was learned in the on-campus session.
- All students asked for the session to be recorded.

  The next step in this new teaching programme is to offer further *E-live* practical sessions to new cohorts of students, improve the presentation by the demonstrators, and ask participating students to complete a more-detailed feedback questionnaire.

Individual interviews of students who complete the experiments hands-on and remotely will be also be considered.

We see numerous implications of the use of this technology for education practice in both engineering and other fields of science. Web-conferencing could certainly be applied to practicals in other fields. For instance, the fluid-mechanics practicals described by Abdel-Salam (2012), which were delivered via video, could be presented by the means described here. Indeed, many lab practicals could be presented to distance students through web-conferencing.

Conclusion

Students who study undergraduate engineering by means of distance engineering face significant challenges in completing the necessary practical work associated with the course. In a first-year physics unit and also in a first-year materials unit, the web-conferencing software *E-Live* has been used for the first time to deliver “virtual lab sessions” in real time to off-campus students. Marks for lab reports by the participating students were comparable to the corresponding marks from students who completed the experiments hands-on. Feedback from the participating students was positive, and the authors have been encouraged to offer practicals in this manner to future cohorts.

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