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Physics Practicals for Distance Education in an Undergraduate Engineering Course

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BACKGROUND

Providing engineering practicals to undergraduates by means of distance education is a significant challenge. The past 30 years have seen the rapid development of the distance education. For many years, Deakin University has offered a full Bachelor of Engineering degree programme via distance education. All first-year students study a unit in physics. This unit includes practicals. Providing practical experiences to students is distance education's greatest challenge.

PURPOSE

The purpose of this work was to develop the means for off-campus students to complete practical exercises in first-year engineering physics. The solution to the problem also had to comply with accreditation requirements set by Engineers Australia.

METHOD

The long-term solution to the problem was running on-campus lab classes either on weekends or as part of the annual first-year residential school for engineering professional practice. Students work was assessed by means of standard laboratory reports. On-campus marks and off-campus lab marks have been collected and compared over the past 12 years.

RESULTS

The results indicate that the off-campus lab experience is similar to the on-campus experience. Marks for the two cohorts were comparable. Those few students who completed their pracs at home faced and overcame significant challenges.

CONCLUSIONS

We found that performance in their lab reports for off-campus students was similar to that of the on-campus students. Accreditation requirements has shifted the focus from developing activities that students could perform at home to offering timely and efficient on-campus lab classes for off-campus students. Future work will focus on on-campus lab classes in accordance with accreditation requirements and perhaps on-line broadcasts of prac classes for those students who cannot attend lab on-campus.

KEY WORDS

Distance education, off-campus laboratories.

Introduction

In any course in engineering, teaching practical skills, both in and out of the laboratory, is vital. In most cases, the practical skills learned are equally as important as the theoretical material. Practical education in engineering courses has many benefits:

- It links the real word with the theory of the subject taught.
- It allows students to physically experience at least some of the engineering content taught in the course.
- It teaches and allows the students to practice essential technical skills required by all engineers.
- It supports student learning in experimental design and measurement.
- It gives the students experience in experimental record keeping.

Most engineering courses begin with a foundation unit in physics. In physics, students learn the fundamental science which forms the foundations of specific engineering disciplines. Students begin to learn how to apply mathematics to real-world technical problems and practice the skills they learn. In physics teaching, laboratory practicals almost always accompany the theoretical part of the subject. In spite of pressures to reduce the amount of practical work in engineering courses, recent work by Bhathal (2011) has found that students prefer to complete real practicals as against, for instance, computer simulations that teach similar content.

The past 30 years have seen the rapid development of the “open university”, where university courses are taught by means of distance education. This arrangement allows many students to complete a university course when otherwise they would be prevented from doing so by work obligations, family situations, or being located a long distance from a university campus (Cleveland-Innes and Garrison, 2010). Many universities throughout the world offer distance- education and on-line learning programmes in a wide variety of disciplines.

The provision of distance-education courses remains limited in technical fields such as science and engineering. In engineering, the vast majority of distance-education courses that we have seen lies in non-laboratory courses, mostly at the post-graduate level. Distance-education courses at the undergraduate level, world-wide, seems limited to small numbers of individual subjects, especially outside Australia. The chief difficulty in offering undergraduate courses in engineering via distance education is providing students with practical experience, especially in the laboratory, where access to specialised equipment and expertise is required (Krute, 2012). This has been found to be a great challenge (Walkington, 1994; Alexander, 2003; Anastasiadis, 2006).

To allow distance students to complete laboratory practicals without attending on-campus sessions, a number of general approaches have been taken (Castro, 2001; Nelayev, 2002). One, very common in electronics teaching, is for the students to perform practical exercises by computer simulation (Ferguson, 1995; Parish, 2002; Margalef, 2007). Another solution is to provide students with specific experiments that can be operated by remote control via the Internet. Again this is especially popular in electronics and electrical engineering, but has been employed in other fields of engineering as well (Casini, 2001; Ko, 2000; Fernao-Pires, 2008, Lindsay, 2005; Lowe, 2009, Kist, 2012). In electrical and electronics engineering, some schools distribute experimental kits to students so their lab exercises can be performed off-campus (Long, 2004, Millard, 2008, Hendricks, 2009, Warren, 2010).

Since the early 1990's, Deakin University has offered a fully accredited Bachelor of Engineering course both in on-campus mode and off-campus mode (Briggs, 1995; Long and Baskaran, 2004). Deakin offers degree programs in civil engineering, electrical and electronics, mechatronics and robotics, and mechanical engineering, with a current undergraduate student population of approximately 570 EFTSL. 25-30% of present enrolments are off-campus. We have faced the same difficulties offering practical education to our students as has been noted above. We have also employed each of the solutions just mentioned in delivering practicals to our distance-ed., off-campus students. Our best successes are in electronics and mechatronics (Hall, 2006; Long, 2008 and 2012; Jones, 2003; Joordens, 1998). We have had some success in manufacturing and mechanical engineering (Ferguson, 1995 and 1999; Lemckert, 1996 and 2002; Florance, 1997). Our present endeavour is to extend off-campus, practical learning to the other fields of engineering that we teach, beginning at first year and then extending to the later years.

At Deakin University, all first-year engineering students enrol in the unit SEP101, Engineering Physics. This unit includes six practical experiments. The off-campus cohort includes students who live locally but have full-time jobs, students who live up to 100 km away from the campus, interstate students, and a few overseas students (domestic students currently living outside Australia). The problem exists on how to deliver comparable practical experiences to all students in the cohort, both on and off campus. The aim of this work was to find a solution. This paper presents how we have addressed this problem of delivering a laboratory experience to off-campus students, comparing the delivery and performance of off-campus students as compared with the more traditional on-campus cohort. We present the results on academic performance over the years 1997-2010.

SEP101 Engineering Physics and its Practical Programme

SEP101 Engineering Physics is a one-semester, calculus-based unit in introductory physics for engineers. 90% of the students enrolled study engineering. The reminder is students in science or IT. About 5% of on-campus enrolments are students studying biomedical sciences. For the years 1997-2010, the unit's 12-week academic content comprised six weeks of basic mechanics, one week of fluid mechanics, and five weeks of basic electricity and DC circuits. The laboratory programme reflected this curriculum (table 1). On-campus students attended three-hour bi-weekly lab sessions throughout semester. Student work was completed by submitting a basic hand-written report at the end of each session. Demonstrators marked each report against completeness of experimental work, report structure, results, and use of English. The report marks were on a scale of one to ten, ten being the top score.

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	DC electric circuits
6	The capacitor and the RC circuit

Off-campus students were given the option of attending a one-day on-campus lab session on a Saturday during semester, or performing six experiments at home with materials and equipment they assembled themselves. The majority of off-campus students attended the Saturday sessions. A Saturday session was eight hours long with a short break for lunch. One or two demonstrators attended to assist students with their work. Students collected the data for their six experiments during this session, and completed the lab reports at home. The same demonstrators marked both on-campus and off-campus reports.

Each year one to three off-campus students performed their experiments at home. To make this easier for this small number, a set of supplementary experiments were offered from which a student could choose (table 2).

Table 2: Supplementary lab experiments available for off-campus students who performed practicals at home.

Experiment	Activity
7	Elastic properties of steel wire
8	DC Wheatstone bridge
9	The helical spring and Hooke's Law
10	Collisions of balls in two dimensions
11	Moment of inertia of cylindrical and spherical objects
12	Characteristics of a DC multimeter
13	Remote experiment: Flow over a Weir

The supplementary experiments included the remote experiment Flow over a Weir, developed earlier as a means for off-campus students to perform a real-time experiment in engineering via the Internet (Lemckert, 1996; 1997; and 2002).

In 2005 Engineers Australia issued guidelines for universities that offered a Bachelor of Engineering degree by means of distance education (Engineers Australia, 2005; Palmer, 2005). Universities that provide distance education in engineering, including Deakin University, were required to run residential schools for two weeks in each full year of study. The first week of the residential school introduced the students to engineering professional practice. The second week was for students to attend laboratory practicals. Deakin offered its first-year residential school in semester one, while on-campus classes were in session. Off-campus students enrolled in SEP101 also enrolled in SEB121, Management Fundamentals for Engineers and Scientists. Distance students performed the physics practicals on-campus in the second week of the residential school. These lab sessions were Monday-Friday mornings. Most of these students performed experiment No. 1 on their own outside of class time. Usually, experiments 2 and 3 were performed on Monday, No. 4 on Tuesday, No. 5 on Wednesday, and No. 6 on Thursday. Friday was reserved for students to finish up and write their reports. By the end of the residential school, participants were able to hand in their completed lab reports for assessment.

From 2005 onwards, the only students who performed their practicals at home were domestic students posted overseas at the time of enrolment.

Results

Enrolment numbers and marks for lab reports were tracked for both on-campus and off-campus students for the years 1997-2010. Figure 1 shows the on-campus and off-campus enrolments during this period. The average report marks for both cohorts are shown in figure 2.

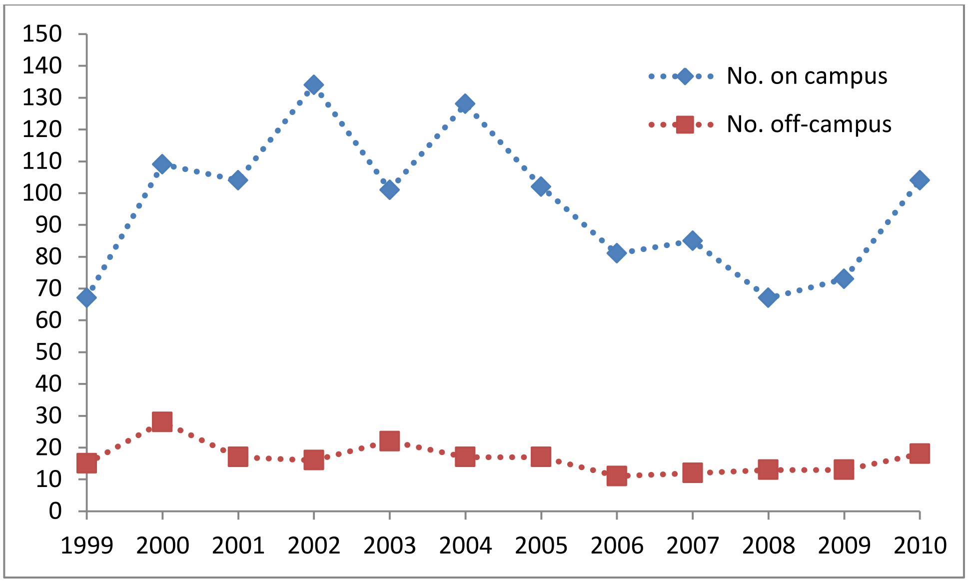

Figure 1: Off-campus and on-campus enrolment numbers for 1999–2010.

While on-campus enrolment numbers showed considerable variation during this time (67 in 1998 and 2008 to 134 in 2002), the off-campus numbers are much more steady, averaging around 16 students. Up to 2006, the average lab mark for off-campus students was about 10% higher than the average mark for on-campus students. These marks are consistent with similar trends seen across the Deakin Engineering School. A study completed in 2002 indicated that the overall Engineering marks are higher for off-campus students than for on-campus students (Palmer, 2002). The trend reverses, however, in 2007. From then onwards, the on-campus marks are on average 9% higher than the corresponding off-campus marks. This interesting result deserves closer investigation to determine its statistical significance and to see if similar trends are seen across the school. Our earlier study of practical performance between on-campus and off-campus students in electronics revealed a smaller gap (8% or less) between on-campus marks and off-campus marks over the same time frame (Long, 2012).

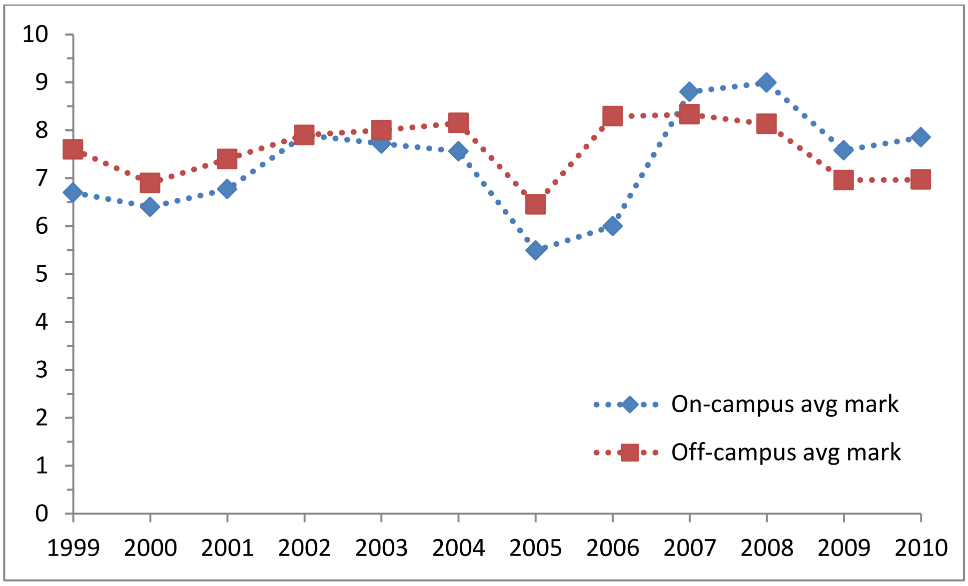

Figure 2: Off-campus and on-campus average report marks for 1999–2010.

In any case the fact that the on-campus marks and off-campus marks on average differ by no more than 10% indicate that the off-campus lab experience is at least comparable to the on-campus experience. Student feedback on the practical experience supports this claim.

Discussion

Those off-campus students who completed their practicals at home found the exercise quite difficult, especially those posted overseas. Their usual procedure was to visit a local school and borrow the equipment necessary to complete six experiments. Actually two experiments are straightforward to complete at home – namely the Excel exercise and the pendulum experiment. A few students had access to an electronics workshop. In those cases assembling the gear necessary for the electrical experiments was achievable. A good deal of communication with the lecturer was necessary to guide the students through their experiments.

Some off-campus students showed great initiative and ingenuity in collecting the equipment necessary to complete the experiments. An example of this was a student in central New South Wales who conducted experiment 4 at home. In this practical (figure 3), the students used the terminal velocity of a steel ball falling through a thick fluid to measure the fluid's viscosity (Worsnop and Flint, pp. 148–149). In this experiment, a transparent but viscous fluid was necessary. Castor oil and glycerine were typical. A 2.5-mm-diameter steel pellet was dropped a known distance after terminal velocity was reached, and the fall time was recorded. For a typical off-campus student working from home, especially if he lives in a remote or regional location, obtaining such fluids in sufficient quantities (up to 2000 ml) can be nearly impossible. In this instance, the student experimented with several viscous fluids, including motor oil, cooking oil, molasses, and honey. The motor oil, while thick enough, was not transparent. The cooking oil, while transparent, was not thick enough. The student settled on refined honey, which had the two necessary properties to perform a successful experiment. A graduated cylinder, stopwatch, and metre rule were obtained from the local high school. The steel pellets and a micrometre were borrowed from a local mechanic. The honey was purchased from the local grocer. To this student, the financial outlay necessary to complete the six experiments was much less than travel and accommodation to the main campus in Victoria, and student benefited from the experience of having to assemble materials and re-design the experiment.

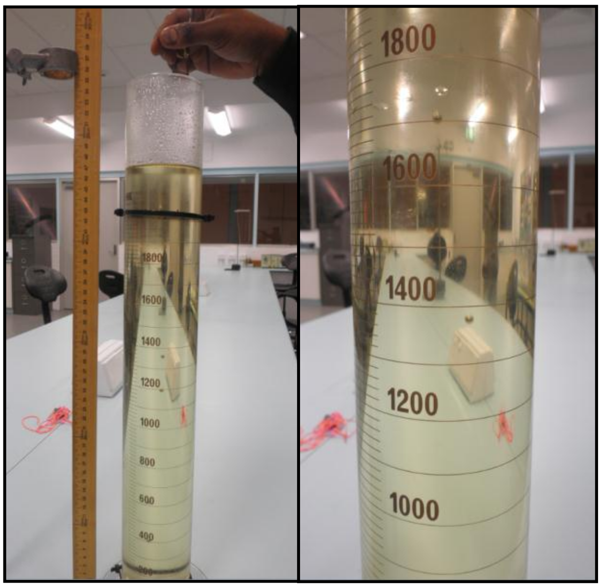

Figure 3: Experiment measuring the viscous properties of castor oil.

A very important issue that needs to be fully debated is whether it is, in fact, necessary to require off-campus students to attend some on-campus practical classes. The present arrangement in SEP101 complies with the requirements set by the Engineers Australia Accreditation Board. From Deakin University's work in distance education, and work published by others in the literature cited above, there is plenty of evidence to suggest that lab practicals can be designed such that off-campus and on-campus performance are essentially the same. Compelling arguments are beginning to appear suggesting that residential schools for off-campus students should not be made mandatory by accrediting bodies (Palmer, 2008, Palmer and Hall, 2008). This is worthy of further investigation.

Future Developments

In 2011 the curriculum of SEP101 was revised to accommodate a new course in civil engineering. The content is entirely mechanics now. Hence the electrical experiments have been removed and replaced by other mechanics exercises. Again the vast majority of off-campus students perform their experiments on-campus at the engineering professional-practice residential school. However there are still a very small group of students who are not able to attend the residential school, sometimes because they are posted overseas. To allow these students to complete their physics practicals, we are experimenting with broadcasting real-time practical sessions over the Internet by means of the Elluminate-Live web-conferencing software package. An initial trial of two lab sessions broadcasted by Elluminate-Live produced positive results and was welcomed by the participating students. Perhaps not the ideal solution, but at least one other study found no significant difference in academic performance between two groups of engineering students, once which completed a real fluid-mechanics practical in the lab and another that only watched a video of the practical being performed (Abdel-Salem, 2012).

Conclusion

Providing practical experience to students studying engineering by means of distance education is a significant challenge for the engineering educator. We have been providing such an experience to distance students in first-year physics for several years. Our off-campus practical programme has been a mixture of on-campus classes on weekends or at dedicated engineering residential schools, at-home performance of the pracs with locally available equipment, a remote-lab experiment in fluid mechanics, and most recently a live broadcast of practical sessions over the Internet. Student performance in their practicals was monitored by means of marked lab reports.

We found that performance in their lab reports for off-campus students was similar to that of the on-campus students. Accreditation requirements has shifted the focus from developing activities that students could perform at home to offering timely and efficient on-campus lab classes for off-campus students. Future work will focus on on-campus lab classes in accordance with accreditation requirements and on-line broadcasts of practical classes for those students who are not able to attend on-campus sessions.

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