ENGINEERING DISTANCE EDUCATION AT DEAKIN UNIVERSITY AUSTRALIA

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ABSTRACT

Increasing numbers of engineering departments are interested in offering their programs by distance education. These schools grapple with several difficulties and issues associated with distance education: course structure, communication with students, delivery of course material, delivery of exams, accreditation, equity between on-campus and off-campus students, and especially the delivery of practical training.

In the early 1990’s, Deakin University faced these same problems when it commenced teaching undergraduate engineering by distance education. It now offers a full Bachelor of Engineering degree in both on-campus and off-campus mode, with majors that include civil, mechanical, electrical/electronics, and mechatronics. Student cohorts are approximately 72% on-campus, 28% off-campus. Accredited by Engineers Australia and part of the Washington Accord, Deakin has adapted to advances in communications technology and changes in education design. The future direction of the School includes an emphasis on design-oriented, project-based learning and “flipping the classroom”. As a result, differences between the more traditional off-campus and on-campus cohorts are becoming increasingly blurred.

Keywords
Distance education, Continuing Engineering Education, On-line learning, Off-campus teaching.

INTRODUCTION

The need to be college-educated in order to pursue a professional career has increased significantly over the past 50 years. In the 1960’s a two-year college diploma or associate degree was sufficient to begin a career in many fields. By the 1980’s a bachelor’s degree became the norm. Now in the 21st century, a master’s degree is becoming the standard in many disciplines. With these changes one sees an ever increasing demand for post-high-school education. At the same time, there has been a rise in non-traditional means of providing education. Distance education has grown from small correspondence courses to a widely-accepted way of providing higher education to those who otherwise would not be able to access it [1]. In the past 15 years, the trend has accelerated because of the rise of rapid Internet communication. In the past 10 years, “distance education” has more often been called “on-line learning,” and sometimes “flexible education.” Potential students who benefit from the flexibility brought by distance education include those in full-time employment, those who live temporarily overseas from their country of residence, those who travel for work for long periods of time, people who are house-bound by disability or illness, and even the incarcerated.

The discipline of engineering has been slower to take up distance education as a means of training future engineers than other fields such as humanities or business. Nonetheless, an increasing number of
engineering schools are trialling courses taught by distance education [2-4]. One reason for this is that providing education “on-line” has made delivering course materials much easier. In the late 1990’s course material was typically delivered through the post. Study materials were principally paper-based: textbooks, printed study guides, assignments delivered to teachers and returned to the students by mail. Now almost all course and learning materials can be delivered via web-sites. Sophisticated learning-management systems now exist to manage everything from text delivery to assignment submission to class communication. Video recording of lectures is also becoming common, and up-loading video recordings to course web-sites is now straightforward and routine.

Providing students with practical education is one of the biggest challenges faced by educators teaching engineering (and science) by distance education. The obvious solution to this problem is to run dedicated practical or lab classes on weekends or evenings. This works for off-campus students who live close to the school or university, but is impractical for students who live more than a day’s drive from the home campus.

Australia is a large continent with a small population. Even though most people live in a handful of coastal cities, there are still plenty of potential students who live in remote towns, mines, farms and cattle stations. Distance education in Australia goes back to the 1920’s, with early correspondence courses [5]. The engineering profession here recognised that distance education has a role to play in bringing engineering education to remote areas [6]. Thus the question arises: is it possible to train and qualify engineers at the undergraduate level by means of distance education, in difficult conditions such as those found in Australia? “Training” in this case means fully training a student with a high-school education, perhaps with some industrial experience, over a four-year period, qualifying him with a full undergraduate degree in engineering.

DEAKIN UNIVERSITY SCHOOL OF ENGINEERING

Founded in 1974, Deakin University operates from four campuses in Melbourne, Geelong, and Warrnambool, Victoria, with an enrolment of 45,000 students (30,500 equivalent full time) [7, 8]. Originally designed to offer courses both on-campus and by distance education, about 30% of its students study in off-campus mode. About 65% of its student body is between the ages of 20 and 24, and 27% is between the ages of 25 to 40.

The present School of Engineering was founded in 1991, with the mission to offer innovative courses, and be a major provider of distance education in engineering [9, 10]. At the undergraduate level, Deakin currently offers four engineering majors:

- Civil
- Mechanical
- Mechatronics
- Electrical and electronics

Deakin’s Bachelor of Engineering takes four years (full-time) to complete. It is accredited by Engineers Australia [11], and the education design is guided by the principles outlined in the Engineers Australia list of competencies for graduate engineers [12]. The fundamental competencies required by graduate engineers in Australia are centered around three key areas: knowledge and skill base appropriate to the specific engineering discipline; ability to apply engineering methods, tools, and resources; professional and personal attributes related to ethics, communication, creativity, self-management, and teamwork. Engineers Australia is also a signatory to the Washington Accord, an international agreement that
accredits engineering courses world-wide, allowing an engineering who completes his qualifications in Australia to be employed as an engineer in several overseas countries, including the USA [13]. All subjects in this course are offered in both on-campus and off-campus mode. A small selection of subjects are offered in the summer semester off-campus only. Figure 1 shows a typical course structure for one of our majors.

![Course map for the Deakin mechatronics major.](image)

Figure 1: Course map for the Deakin mechatronics major.
The degree itself does not distinguish between off-campus mode and on-campus mode. All students study the same course. During the years of their study, many students change from on-campus to off-campus and vice-versa. The typical off-campus student is between 21 and 40 years old, has a full-time job, often in an engineering field (such as manufacturing or mining), and often has a family. He enrols (part-time) in the off-campus course to increase his educational qualifications and assist with career advancement. Figure 2 shows enrolment statistics in the School of Engineering over the past 15 years. On average, about 28% of the School’s total enrolments have been off-campus. Off-campus students generally take a half-time study load. While the majority of our off-campus students reside in either Melbourne or Geelong, we do have significant numbers living in rural areas, interstate, and even overseas (figure 3 and table 1).

![Figure 2: Undergraduate enrolment data for the School of Engineering over the years 2000–2014.](image)

<table>
<thead>
<tr>
<th>Country or region</th>
<th>Enrolments</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand</td>
<td>70</td>
</tr>
<tr>
<td>Malaysia/Singapore</td>
<td>940</td>
</tr>
<tr>
<td>India and Sri Lanka</td>
<td>20</td>
</tr>
<tr>
<td>China, Hong Kong, Burma and Mongolia</td>
<td>10</td>
</tr>
<tr>
<td>Africa</td>
<td>7</td>
</tr>
<tr>
<td>North America</td>
<td>6</td>
</tr>
<tr>
<td>Europe</td>
<td>10</td>
</tr>
<tr>
<td>Middle-East</td>
<td>6</td>
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</tbody>
</table>
DELIVERING TEACHING MATERIALS to OFF-CAMPUS STUDENTS

Apart from laboratory practicals and textbooks, nearly all course material is delivered on-line [14] by means of course websites (figure 4). The present learning-management system is built on the Desire-2-Learn software platform [15].

Typical components of a course website includes:

- A welcome and announcement page.
- A unit overview area, containing the syllabus, assignments, schedule, and list of teaching staff.
- A laboratory practicals area.
- On-line study guides, topic-by-topic, and week-by-week.
- An on-line discussion forum, where students can communicate with each other and with the teaching staff [16].
- An assignment drop-box, where students can upload their work for assessment [17].
- An exam revision area.

Course materials are developed by the lecturers, with the assistance of a professional team of educational developers, editors, and webmasters. Until recently, dedicated software and videos needed for teaching were posted to students on CD’s [18]. Now videos are streamed via the course websites, and software is being delivered by means of a remote-desktop service. Courses are evaluated yearly by the students [19] and regularly reviewed to keep them up-to-date with engineering developments, improvements in communication technology, and student expectations [20].

A recent innovation (figure 5) is the delivery of real-time tutorials by means of the web-conferencing software Elluminate-Live (E-live) [21]. This overcomes the delay in communication between lecturer and student. It also goes a long way towards alleviating the isolation that many off-campus students feel, especially those in remote areas of Australia. Since 2013, all engineering subjects have delivered web-based real-time tutorials, with a very positive response from the students [22].
Figure 4: Sample home page from the course website for first-year engineering physics.

Figure 5: Example of using web-conferencing software to deliver a tutorial to off-campus students in first-year materials science.
LABORATORY and PRACTICAL WORK

Essential in any engineering degree program is practical experience through lab classes, workshops, and work placements [23]. All accredited engineering degrees contain a series of robust laboratory exercises to give students experience in practical work, witness first-hand science and engineering concepts, practice the use of engineering instruments, software, and tools, and in general become familiar with the hands-on nature of engineering. Students themselves recognize the importance of practical work in their study [24]. In distance education and online learning, this is the biggest challenge for the educator [25]. How does one transmit practical knowledge to distance students? Deakin has addressed this problem in eight basic ways [26]:

1. weekend lab classes (The majority of our subjects do this.) [27]
2. video-recorded experiments (figure 6)
3. computer simulations [28]
4. lab kits and associated at-home experiments [29, 30]
5. remote-controlled lab experiments [31]
6. at-home design projects [32, 33]
7. web broadcasting of lab classes [34]
8. an intensive residential school.

Figure 6: Images and data of hot-rolling steel from a laboratory video in third-year manufacturing. The video is distributed to off-campus students as part of their teaching materials.

Since 2005, to satisfy accreditation requirements, we have run on-campus residential schools for off-campus students [35]. The purpose of the residential schools is for off-campus students to meet the engineering faculty, gain some first-hand exposure to engineering practice by means of guest lectures
and site visits, engage in group activities, meet other students, perform practical exercises and lab classes, and deliver in-person project presentations. The requirements were developed by Engineers Australia in consultation with members of the Washington Accord [36], and modelled after residential schools developed by the University of Southern Queensland [37, 38]. The requirement to run these residential schools generated considerable debate [39, 40]. Our experience suggests that at least in the first two years of an engineering course, it is possible to develop a robust off-campus practical program that delivers the same educational outcomes as a corresponding on-campus program, and satisfies the common objectives in engineering laboratory instruction.

EXAMPLE OF A PRACTICAL EXERCISE FOR OFF-CAMPUS DELIVERY

One of the difficulties of teaching off-campus students is familiarizing them with physical devices. The use of programmable logic controllers (PLC) is one such instance. The PLC is a device that is used to control industrial processes. One could require off-campus students to attend an on-campus class to see a PLC and its connection to the real world. However, to do this one needs an industrial process to be controlled in addition to the PLC controlling it. This can become expensive; most universities will only have one or two physical systems that represent an industrial process. A PLC simulator could give the same experience. While the PLC controls a system, learning to use a PLC is mainly about how to program the PLC. PLC’s used for learning are often connected to a series of switches and lights which are used to simulate the real system. In those PLC’s that are connected to a scale version of an actual industrial process, we normally find that the process is greatly simplified. Simulation then gives us the ability to design and simulate far more complex industrial processes at a small cost. A further benefit of simulated approach is that once a PLC is installed and connected to the industrial process, we find that this process is no longer viewed apart from a model of it on a computer monitor. Therefore in this case, a simulator behaves very much like the real system, and as such is beneficial in teaching students.

Due to the lack of an adequate commercial package in Australia, we developed the PLC Master software [41]. Our simulator uses ladder logic. The PLC simulator has an editable window with eight columns in which the ladder logic is drawn. In this graphical interface contacts and coils (inputs and outputs) plus counters, timers, and flags can be selected and placed on the grid with a mouse. This works in a very similar fashion to most commercial PLC ladder-logic packages. The advantage to the student is in the simulation phase. Just like a PLC that is connected to switches and LEDs, the simulator allows the student to see the status of the inputs, outputs, flags, timers and counters. The simulator's main advantage however is in the case studies. The simulator is able to display five case studies based on different process scenarios. One such case study is shown in figure 7. The simulator is used by both on-campus and off-campus students in identical practical exercises.

DISCUSSION

As much as possible, the assignments, exams, assessment, and practicals in all our courses are identical for on-campus and off-campus. Exams for off-campus students are run in supervised exam centers located throughout Australia and overseas. The University has put in place both administrative infrastructure and quality-assurance processes, so that textbooks and library resources can be efficiently delivered anywhere in the world; hard-copy assignments (such as project posters or lab notebooks) may be collected, tracked, and returned; course materials are professionally produced and updated; and exam papers are delivered for grading [8]. In addition to high-quality lecturing staff, course materials, and administration, we have found that there are other important factors that contribute to the success of an off-campus program in undergraduate engineering, and its appeal to potential students:
Figure 7: PLC Master showing ladder logic and a case study: a car boom gate is controlled either by a valid key card or by a guard in a guardhouse.

- Deakin’s Bachelor of Engineering degree does not distinguish between off-campus and on-campus.
- The degree is fully accredited and fulfils the requirements set by the Washington Accord. Thus students completing the degree qualify as graduate engineers, both in Australia and overseas.
- There is no difference in tuition fees between on-campus and off-campus.
- All engineering subjects are offered on on-campus mode and off-campus mode. Thus all subjects have a mix of both kinds of students.
- The School has a robust research program which enhances and adds value to the undergraduate courses.
- The School maintains several research and teaching partnerships with industry and other universities. Both off-campus and on-campus students benefit from these partnerships.
- Off-campus students are encouraged to select projects from within their place of employment, which very often is engineering in nature.

CURRENT and FUTURE DEVELOPMENTS -

Deakin’s School of Engineering is embarking along three new paths that will impact the nature of its courses and the quality of its off-campus teaching. Firstly, all engineering majors are being re-worked to implement a collaborative, design-led approach to teaching, especially in the third and fourth years. First introduced into mechatronics courses in 1997 [33], the specific approach has been under investigation [42], and for a number of years, practiced in the mechatronics major. It was recently
renamed “project-oriented design-based learning” (PO-DBL) where learning centers around groups of students working together to solve a design problem, learning the necessary engineering concepts and techniques along the way [43]. Presently about 25% of our courses have a design component. The plan is to increase this number significantly. Both off-campus and on-campus students are being consulted as part of the course re-design [44], and modern communication technologies (for example web conferencing and remote-desktop software applications) will enable all students, off-campus and on-campus, to collaborate and work together [45].

The second development is the “Center for Advanced Design in Engineering Training” (CADET), a partnership between Deakin University, local high schools, and community colleges to address the shortage of engineering skills in Australia [46]. CADET will assist the implementation of PO-DBL, and includes a modern teaching facility which is more studio-based than classroom-based. Off-campus students will work with CADET via internet-based communications and attendance at the residential schools.

The final development is the university-wide shift from traditional lecture-tutorial teaching to delivering core content by means of high-quality videos, then using classroom time for workshops, practicals, and problem solving. Called “cloud-based teaching” [47], it represents a fundamental shift in how knowledge and information is transmitted from lecturer to student. The name refers to the application of cloud computing to education [48, 49]. In the more traditional teaching model, fundamental knowledge and concepts are delivered in lectures. Students then apply the knowledge through at-home exercises and sort out learning issues in tutorials. In the cloud-learning model (also known as the flipped-classroom model [50]), the student gains fundamental knowledge and understanding by watching short videos (called “cloud concepts”) on a PC, tablet, or mobile phone. Class time focuses on applying that knowledge by group discussions, practical exercises, and problem solving. For example, in first-year physics, a series of videos has been developed to introduce students to the practical lab experiments (figure 8). The videos introduce the students to the theory of the experiment and demonstrate how to run the lab equipment, which increasingly involve data-loggers and specialized software. Off-campus students, doing their experiments on a Saturday, are pressed for time. The aim of the videos is in part to allow students to begin experimental work immediately on entering the lab, and not spend precious time learning how to set up the equipment and operate the data-loggers. Our School is at an early stage in implementing cloud learning. All lectures are being video-recorded and released to students. Organising the videos into a structure suitable for teaching, producing high-quality cloud-concepts, and obtaining feedback from students will occupy the School for the next three to five years.

It is evident from our experience that the terms “off-campus” and “on-campus” are being blurred into the more general term “blended learning.”

Figure 8: Screen-shot of a video demonstrating how to run a collision experiment in first-year physics.
CONCLUSION

There has been an increased interest in teaching engineering by means of distance education or on-line learning. Many universities offer postgraduate degrees via distance education, and many universities offer individual course subjects by distance education. Due to difficulties in delivery, there are few examples of full bachelor’s degrees in engineering, especially in North America. Deakin University in Australia is one institution that has, for many years, offered a fully accredited Bachelor of Engineering by distance education, with robust and increasing student numbers. Deakin has kept abreast of modern communications technologies and development trends in education. Finally, as suggested by the US-based Sloan Foundation, Deakin has answered the call for universities to offer engineering education “anywhere, anytime” [4].

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