International Conference on Engineering Education and Research "Progress Through Partnership"

Converging Courses to Suit Converging Technologies

Trevor LUND
School of Information Sciences and Engineering, University of Canberra, ACT 2601, Australia. trevor.lund@canberra.edu.au

Neil RUSSELL
School of Education and Professional Studies, Gold Coast Campus, Griffith University, PMB 50 Gold Coast Mail Centre, Queensland 9726, Australia. n.russell@griffith.edu.au

KEYWORDS: *converging technologies, network engineering, virtualisation, constructivist learning*

ABSTRACT: *The convergence occurring within the sectors of industry which are served by our engineering courses at the University of Canberra, with the symbiosis between computing and communications technologies in particular, has become a driver for developments in both the underlying technology and its applications. Web technology, mobile communications, and wireless networks are examples of this convergence and symbiosis. With the introduction of a new course this year, we are able to bring together the previously disparate engineering courses into a unified and coherent offering and address modern trends in the industry and its need for graduates with appropriate education and skills. The integration of the three former courses of engineering (computer engineering, electronics and telecommunications engineering, software engineering) into one course also facilitates the introduction of group work and a new approach to pedagogy across a spectrum of engineering disciplines, to better prepare our graduates for the profession.*

The specialisation streams within this new degree range from the hardware end of the spectrum in which students study telecommunications systems, through computer systems to software engineering. The streams within the course share a common core of roughly half the content, and the boundaries between them are not sharply defined, so it is possible for students to commence tailoring the course to suit their own needs after their first year.

This paper outlines and discusses the planning process, from the initial consultation with stakeholders and the formation of an industry reference group, to the championing of a detailed proposal through the University course approval process. The implementation of the course including re-invigorated methods for teaching and learning together with expected benefits for students, staff, and the community are described.

1 INTRODUCTION

The teaching of engineering at the University of Canberra has always been a small operation (the University itself is not large with an enrolment of about 10,000), and has covered only fields related to electronics and computing. This has been appropriate, given that Canberra was set up as the base for the federal government of Australia, and contains no heavy industry, but has grown a number of high-technology companies. The larger cities across Australia with their larger and wider industry base, all house large and comprehensive schools of engineering within their universities, so the University of Canberra attempts to fill a niche market.

The electronics and telecommunications engineering course, and the computer engineering course, had their roots in different parts of the University, and although the groups which spawned them were later brought together in the same faculty, the courses retained a significant organisational separation, despite having a virtually common first year and some shared subjects in later years. When the software engineering course was introduced later, largely as a development of the Bachelor of Information Technology, it again had a distinctly separate identity, despite being taught in the same faculty.

There is now considerable convergence occurring within the technology industry which is served by our engineering courses, with the symbiosis between computing and communications becoming a driver for developments in both the underlying technology and its applications. Web technology, mobile communications, and wireless networks are examples of this convergence and symbiosis. There is a need to bring together the previously disparate courses into a unified and coherent offering to address these modern trends in the industry and brings our courses up to date. The integration of the three strands of engineering into one course not only facilitates the introduction of group work across a spectrum of engineering disciplines, it also opens up opportunities for new ways of organising the teaching and learning to better prepare our graduates for the profession. This integration reflects the coherence of the School of Information Sciences and Engineering, formed from recent mergers of disparate Schools.

2 PLANNING PROCESS

The planning process began with a series of meetings of the teaching staff who could be considered stakeholders within each of the three pre-existing courses. These meetings were chaired by a senior member of the engineering staff, but initially were of one discipline group at a time, probing for commonality and compromise between the courses. This process was aided by the impending merger of the Schools currently teaching the courses into a single School, bringing all of those involved in the teaching of engineering under a single umbrella. After a couple of iterations, sufficient commonality had emerged for a skeleton structure for a combined course to be drawn up and brought before the whole (combined) School for discussion.

Following the agreement in principle reached at the meeting, a project leader was appointed to expedite the detailed planning of the course and shepherd a proposal for its introduction through the University’s approval process – with the aim of starting the new course at the start of the next academic year. The project leader recruited a small, cohesive committee to achieve this purpose – basically just one representative from each of the discipline groups with a contribution to the teaching of the course. Because of the tight time-frame, each of these representatives was expected to be able to make commitments on behalf of his group, if necessary by informal consultations with his colleagues between meetings of the committee. In this way there should be no surprises when proposals were brought to scheduled meetings of the School for approval.

Because wider consultation is appropriate in the development of courses, and indeed required by the University’s approval process, the committee recruited a “reference group”, so that consultation could be formalised, rather than just informal and anecdotal. In addition the content of potentially similar courses at universities elsewhere in Australia was investigated via the descriptions published on the universities’ web sites.

The proposal developed by the course planning committee needed to make its way through a sequence of committees at School, Division and University level before receiving approval at Academic Board. The modus operandi of the planning committee ensured that very little discussion of the proposal was needed at either School or Division level – because the key points had already been agreed – and the proposal made smooth progress through the remaining levels to receive approval in the desired time-frame.

3 REFERENCE GROUP

3.1 Composition

The members of the reference group were drawn from local industry, from the professional engineering bodies (the IEAust and the IEEE), and from another university in Canberra. The industry representatives came from both the hardware and the software end of the spectrum, and were a mixture, in the main, of graduates and employers of our graduates. These representatives were chosen to provide information on what were the perceived needs of industry, compared with what we had been providing in the education and training of our graduates. Being in Canberra, the capital of Australia, we were able to make contact with the head office of Engineers Australia (formerly known as the Institution of Engineers, Australia), and recruit the person who had coordinated all of the recent accreditations of engineering courses in Australia. The Chairman of the local section of the IEEE was also present, also serving as a graduate and an employer of graduates. The two external academics invited onto the group were the head of an electronics engineering school and the head of a school of computing. With this composition, and just 10 members – we didn’t want too large a group or it would have become unwieldy – we believe that we had recruited a group that would give us good advice and guidance.

3.2 Role in Planning

When the internal planning group had produced a reasonably complete proposal for the purpose and structure of the course, copies of the relevant documents were mailed out to the reference group members, and they were invited to the University for a meeting. Some of the reference group members submitted written comments in addition to participating in the discussion at the University. One member, who was unable to attend the meeting at the University, invited the project leader to his workplace, where he had set up a meeting with a group of his colleagues, selected to cover the range of operations within that company. The recommendations coming out of these meetings were recorded, discussed in subsequent meetings of the internal planning committee, and appropriate changes incorporated in later versions of the course proposal.

3.3 Future Collaboration and Partnerships

It is our intention to follow up on the relationships established, or renewed, in this consultancy process to create continuing partnerships for the education and training of our students, and for research and development projects for the enrichment of our staff. We already have some informal – and invisible – partnerships with industry in that our students are required to obtain a certain amount of professional experience before they graduate (a requirement of Engineers Australia for accreditation), normally via vacation employment. To put these partnerships on a firmer footing will be of significant benefit to both the students and the employers, and will be a project undertaken by the course coordinator for the new course. We have already extended the involvement of the reference group with the University by inviting the members to take part in the judging of some of the activities of our fourth year students, and the awarding of prizes.

4 COURSE STRUCTURE

4.1 Constraints

There were various constraints placed on the plan for a new course. First and foremost is the need to retain the accreditation of Engineers Australia, so that graduates can obtain a full professional qualification via corporate membership of the Institution – and indeed gain mobility through the international recognition of their qualification through the Washington Accord, of which Engineers Australia is a signatory. The second constraint comes from the internal University requirement that each course leading to the degree of bachelor contain an identifiable development of "generic skills" (*eg*: communication skills, information literacy and numeracy, problem solving, the ability to work with others and contribute positively to the workplace, a sense of social responsibility and professional ethics, etc.). Fortunately, the University requirements are mainly just a subset of the professional institution requirements – and just an articulation of what we, as engineering educators, would expect of our students anyway – but documenting the course's development of these skills provided a useful check within our course planning process, and a start at developing a system for the students to record their acquisition of these skills in a learning portfolio.

4.2 Challenges

Given that we are fully cognisant of, and fully in agreement with the professional accreditation requirements, and that our existing courses met the requirements, the main constraint we faced was that of resources. In a climate of shrinking staff and student numbers the main challenge was to design an attractive course which could manage the sometimes conflicting aims of breadth, depth, flexibility and coherence. We were certainly expected to reduce the number of subjects taught by the engineering staff compared with the number in the existing courses, yet we wished to be able to make available to the students a comparable breadth and depth of experience – and still not constrain them too tightly within existing discipline boundaries.

4.3 Solutions with Flexibility

Our solution was essentially two pronged. We increased the amount of commonality between the streams – the software engineers do more maths than before, and the telecommunications engineers do more programming than before, for instance – and we redesigned some of the subjects so that the prerequisite structure could be more flexible, so that those subjects could be more easily accessed by students following different paths through their course. In this fashion, we have attempted to implement the aims extolled at the start of this paper, *viz* to create a converging course to prepare students for the convergence of technologies.

Sem 1	Mathematics 1	Introduction to Software Engineering	Engineering Science	Introduction to Computer Engineering
Sem 2	Mathematics 2	Software Technology 1	Database Design	Introduction to Telecommunications Engineering
Sem 3	Engineering Statistics	Engineering Management 2A	Software Technology 2	Information Systems Design
Sem 4	Linear Algebra	Engineering Management 2B	System Software	Information Systems Analysis and Modelling
Sem 5	Maths Elective	Engineering Management 3A	Signal Processing or Elective for SE Engineers	Software Engineering 3A
Sem 6	Maths Elective	Engineering Management 3B	Digital Communication Networks (Network programming)	Object Oriented Software Design
Sem 7	Engineering Project (Common structure for all streams)		Advanced Topics in Engineering (Selection of Topical modules from all streams)/Elective for SE	Distributed Systems Technology
Sem 8			Systems Engineering Studies (Case Studies from all streams)	Computing Elective

Mathematics	Management	Common Core	Science/Electronics	Engineering Specialisation

Figure 1. Course structure, showing choices for a student specialising in software engineering.

Figure 1 provides a representation of the structure of the course, showing where the commonality between the streams occurs, and where the differentiation is possible. The first year is common to all streams, as is the "Engineering Management" stream. The post-first year column on the right is where most of the specialisation takes place – figure 1 shows the choices likely for a student of software engineering. Some choice even flows over into the central column (labelled "core"), mainly to allow more subtle grades of variation for the software engineers away from hardware – the students with a hardware orientation, whether specialising in computer engineering or telecommunications engineering, tend to take the same subjects.

4.4 Coherence and Integration

The maths stream varies a little too, according to the specialisation stream taken – some of the subjects selected, particularly for the telecommunications stream will have specific maths prerequisites. The software engineering students get the opportunity to shorten the maths stream in order to allow more space for computing electives. The content of the mathematics component of the course and its scheduling has been carefully planned so that the relevant material appears "just in time" to support and integrate with the mainstream components of the course. The cross-linking and interdependence of these components should as a result, be made apparent to the students and enhance their motivation for learning.

Throughout the course, whatever the specialisation, the teaching and learning approach will emphasise learning for problem solving. Typical assignments involve design and problem solving in applications of the principles presented to the students. Some of these assignments are mini-projects, and this style of teaching commences in the very first semester of the course, so that the students are adequately prepared for the major project that they undertake in the final year. This final year project, the capstone subject for the course, brings together the principles and skills learned by the students in the course in a practical and productive fashion. It provides at the one time both an integrating and a broadening experience as not only do project groups interact with all of the other project groups in the course, but any given project group will normally comprise students from more than one stream.

The prime document specifying the course structure, the "Determination of Course Particulars" (DCP), has been written in such a way that a student can fit into the picture of figure 1, a sequence of subjects that fit the rules for his or her chosen specialisation, but which look much like a sequence chosen by a student from another specialisation. In this way, the boundary between computer engineering and software engineering is fuzzy, as is the boundary between telecommunications engineering and computer engineering. Because of this, students do not have to commit themselves to a particular specialisation even at the start of second year, although they should keep an eye on the DCP to ensure that they have a sufficient combination of "breadth and depth" (as defined by the course developers) to be able to claim a specialisation to be incorporated in the name of the degree.

5 IMPLEMENTATION

5.1 Phasing in

The course commenced operation this year, accepting students into the first semester at the end of February. No new intake has been allowed for the pre-existing courses, but those who completed first year in 2003 will continue with their course as originally planned. Students who failed to complete their first year last year will be able to select from the currently available subjects to get an approximate match to enable them to continue with the course for which they enrolled. The second year of the new course will be offered in 2005, the third year in 2006 and so on. At each stage, students who have fallen behind in the pre-existing courses will have the opportunity to choose subjects on offer at the time which make a reasonable match to those that they need to complete their degree, or they may be allowed to transfer to the new course, bearing in mind that they will not be able to complete before the end of 2007.

5.2 Learning Portfolio

As the new course is implemented, we will be introducing a system whereby students will be able to build up a learning portfolio, recording when they acquired the "generic skills". This will improve the students' perception of the importance of these skills, demonstrate how they are woven into the fabric of the course, and potentially provide more evidence to an employer of the capabilities of the student. To facilitate this development, the Director of CELTS (the Centre for Excellence in Learning, Teaching and Scholarship at UC) was recruited to the planning committee to keep the committee informed of new developments in this field, and to aid in the introduction of a formal system. This is expected to lead to this being amongst the first courses in Australia to introduce the possibility of students building up a portfolio to record their acquisition of generic skills.

5.3 Development of Teaching Staff

As the nature of the engineering course changes over the next few years, the teaching staff will be adjusting both the nature of their expertise and the nature of their teaching, with a degree of enthusiasm. For instance, at some stages of the planning, some staff were heard to say "there's no electronics left in the course", whereas in fact there is just as much, but it looks different. The structure of this course is influenced by the recognition that the emphasis within the engineering profession is moving from devices to systems, and that most engineers will be concerned with large scale integration of systems rather than the detailed design of components. The detailed design of components will be mostly done in only a few specialised locations, where the large teams and expensive infrastructure can be supported. The fact that the Canberra market for engineering graduates is largely concerned with smart engineering rather than heavy engineering has also influenced the content. In a similar vein, the basis of software engineering is becoming more mathematical as employment opportunities open up in such areas as games programming, with the need for high quality computer graphics, and in security and cryptography. Teaching staff will be adjusting their own expertise and approach to teaching to fit these expectations.

6 CHANGES TO TEACHING AND LEARNING

It will be important to develop teaching and learning opportunities for "smart "Engineers that is consistent with or congruent to the nature of the course. Elements of a virtual university approaches will be incorporated into the course as the emphasis in the course moves from devices to systems.

The virtual university is formed and located in cyberspace, which is a virtual space created by the Internet on the World Wide Web. Russell and Russell (1999, p.8) define educational cyberspace as "a cognitive space, accessed by computers, and which allows users in educational contexts to interact with texts and virtual reality". The virtual university has been made possible by computer-enhanced information technology and the recent explosive developments of communication and Internet technologies. In education, the Internet helps different learning styles more effectively and certainly. The virtual university benefits most in this way. Gates (1999, p. 399) makes the claims that:

Some people learn better by reading, some by listening, some by watching someone else do a task, some by doing the task. Most of us learn from some combination of all these methods. And all people have different levels of aptitude and different personalities and life experiences that may motivate them to learn or demotivate them. A highly motivated student can learn from difficult reading materials, where a poorly motivated student needs accessible materials such as a video to learn. New software is helping students learn regardless of learning style or pace.

According to Ryan, Scott, Freeman, and Patel (2000), the process of teaching and learning in a virtual university is mostly undertaken by electronic technology with courses and instructional programs offered through the Internet and other technologically enhanced media. The virtual university offers a different and more advanced mode of distance education than text based distance education. It has the potential to be more interactive than traditional distance education with the use of audio, video and telecommunication systems. Delivery of education materials is potentially more efficient and faster than before, so students gain flexibility of time and space for their study as well as completing their studies in a technology environment that is appropriate to their engineering study program.

Furthermore, Dunn (2001) suggests that a virtual university has more meaning than that of just an advanced mode of distance learning. According to Dunn (2001), the virtual university can offer the potential of instructions without the time and place constraints of traditional university programs. Consequently, it can offer a group-based learning environment, and a similar level of interaction and support to that which takes place in traditional, face-to-face, seminar-style classrooms. All of these benefits can be offered to degree-seeking adult students from all over the world. In more recent times, it has even been regarded as a "threat" to the traditional form of education (Dunn, 2001). Rather than seeing virtual approaches as a threat the engineering courses at Canberra will make use of this virtual learning mode.

6.1 Virtualisation of Higher Education

The displacement of people by machines is a process that has continued for hundreds of years, and a discussion of this process provides perspectives on the ways in which lecturers can consider the challenges posed by computers. It is clear that there are a number of reasons why a new technology might be opposed by existing traditional tertiary educators. In the early stages, the innovation may be seen as impractical, expensive or unsafe. However, a continuing theme is that of the resistance by groups who see new technology as either an economic threat to their livelihood, or an unwelcome change to their way of life.

However, there is a growing concern and fear that money spent on the new technological infrastructure might result in funds being diverted away from the employment of lecturers and so on. There is also growing evidence that infrastructure, hardware, network and Internet costs are expensive initially and increase rather than diminish over time. For example, Griffith University's Internet access costs in 1995 were $50,000 and in 2001 were $1.5 million. In addition, the need for technical support, in-service of academics, etc is an additional, growing funding need. Still, establishing and operating a virtual university would be cost saving as Turoff (1996) analysed that the costs for the development of a virtual university would be less than building any sort of academic building, which would cost approximately $15 million US (Turoff, 1996). However, the issue about the cost saving in the development of a virtual university remains contestable.

6.2 Cameos of Virtual Universities

Dunn (2001) suggests that by 2010, at least 95% of instruction in the U.S. will be digitally enhanced, and the virtual university will be the predominant mode of higher education by 2025. At the moment, in all Australian higher education institutions, at least one of the following on-line learning methods is used:

- Web-based -where the course is dependent on the content and activities on the web site;
- web-enhanced- which improves the learning experience by enrichment and interaction in a way not available through other resources; or
- web-supported- where the web site plays a significant role in the course by providing an alternative means of accessing learning materials

(GFLS, Internal document, 2000, cited in Young, 2001).

There are purely Internet-based universities, where all university activities, from enrolment to graduation, occur in cyber space through the Internet. Delivery of lectures, feedback to students, administration, student services and other resources are available only through the Internet. Jones International and Korean cyber universities, starting in Spring semester 2001, are examples of such Internet based systems. In the following section, descriptions of those are discussed to illustrate the growth of online delivery of higher education programs.

There are distance education institutions in which paper materials were formerly delivered by post, but have now converted to delivery of electronic materials via the Internet. Regent College, University of Phoenix, Western Governors' University, California Virtual University, and Southern Queensland University (in Australia) are other some examples. In these universities, most educational activities are undertaken through the Internet, but off-line campus activities and meetings are still available, though they are limited.

A recent trend has seen virtual universities developing university consortia using Internet technology. Examples of consortia are Universitas 21 and GUA (Global University Alliance). Menser (2001, p.26) observed this development and said:

Universitas 21, which was established in 1997; it has an international network of 18 universities in 10 countries; its Australian members are the University of Melbourne, University of New South Wales and University of Queensland. GUA (Global University Alliance), launched October 2000; it comprises 10 universities and NextEd, a Hong Kong-based online education specialist; its Australian members are RMIT University and the University of South Australia.

There are also on-line corporate training applications. The re-skilling of staff takes place through on line corporate universities such as General Motors, Mcdonald's, Motorola, Sun, Oracle, and Hewlett-Packard (Crock, 2000). Australian examples include the University of Western Sydney with ANSTO, ICI and Caltex, Deakin Australia with Ford, Coles Institute, and Deakin Corrs, Schneider, Australian University Graduate School to short courses, and Monash University's Mt Eliza Business School with Honda Business Institute. Melbourne University Private, established in 1998 by the University of Melbourne, is one of the better examples of this form of operation.

The Canberra engineering courses are moving in the direction of web enhanced and web supported on-line learning approaches.

6.3 Social Change and Forces for Change

There seem to be many reasons for the concept and operation of virtual university is to be developed further. There have been many social changes. For example, Leonard (2000, p.30) stated:

Knowledge industry is changing. Unless we, within institutions of higher education, wish to become obsolete as knowledge sharing and knowledge-dissemination vehicles, we must change too.

The emerging mass of population seeking to access higher education in many developed countries is a recent phenomenon (Taylor, 1999). Generally, life-long learning or adult learning populations in higher education are growing. For example, Lyman (1999) predicts adult learners of 25 years of age or older will make up over half the higher education student population in the United States in the near future. Distance education has been an ever-growing education business. In Australian universities in particular, about 40 per cent of students are now part-time or distance-education students (Flew, 1998). The virtual university has been an effective alternative to the growing demand for potential learners who could not otherwise be accommodated in the traditional higher education systems.

6.4 Virtualisation within this Course

In addition to the provision of lecture materials, subject 'news', and other materials on subject web sites, as has been happening in most subjects for some years now, a Computer Supported Cooperative Work (CSCW) environment will be used to create electronic work spaces for staff and students. As appropriate, CSCW will be used to support discussion between students and/or staff, provide a forum for questions and answers, and enable sharing of information, including sharing of documents within project groups. Apart from facilitating learning within the subjects within which it is used, CSCW will produce learning outcomes of it own, *viz*: the students will appreciate and be able to use some of the functionality of CSCW tools, have the skills to participate in the sharing of information and documents while working in 'virtual' teams, have a knowledge and appreciation of 'netiquette' (the appropriate use of electronic tools to support work), and have the skills to work "anytime/anywhere" or "telecommute". The Information Sciences parts of the School of ISE has been acquiring expertise in the application of CSCW within various of their subjects, and the transfer of the technique to the Engineering subjects will be straightforward.

7 CONSTRUCTIVIST APPROACH TO LEARNING AND VIRTUAL EDUCATION

Constructivist approaches to teaching and learning have been closely identified with virtual universities and have been adopted as part of the overall learning strategy in the engineering program. According to Palloff and Pratt (2001), definitions of what constitutes education and learning are changing because of the changing nature of today's students, economic pressures, and rapid implementation of distance learning courses and programs. The Internet and current constructivist approaches of learning hold that students, through their interaction with one another, the instructor, and their environment, create knowledge and meaning (Palloff & Pratt, 2001). Constructivist approaches of teaching and learning provide a set of guiding principles to help designers and teachers create learner-centred, collaborative environments that support reflective and experiential processes (Jonassen, Davidson, Collins, Campbell, & Bannan Haag, 1995). As the constructivist approaches of teaching and learning provide learner-centred and self-directed learning environments (French, 1999), it is appropriate to investigate the characteristics of learning in virtual universities from the constructivist perspective of teaching and learning.

Researchers such as Duffy and Jonassen (1992, p.3) argue that those favouring constructivist approaches imply that "meaning is imposed on the world by us, rather than existing in the world independently of us." The constructivist approach views that individuals construct knowledge through interpreting their own experiences (Rice & Wilson, 1999). Using this approach, Vrasidas (2000) suggests that knowledge does not exist independent of the learner, but rather knowledge is constructed. The key to learning in constructivism is an active process of constructing, building or transforming knowledge rather than acquiring or transmission of knowledge. Researchers who favour constructivist approaches to explain learning argue that knowledge is acquired through involvement with activities of learning instead of instruction from teachers, imitation or repetition. In a constructivist learning environment, the learners are given the opportunity to negotiate content, assignments, procedures, and deadlines. They have control over their own learning and are provided with the tools, resources, and support necessary to manage their learning and assigned tasks (Vrasidas, 2000).

Jonassen et al. (1995) found that computer-mediated communication, computer-supported intentional learning environments, and computer-supported collaborative work environments all support an approach based on constructive learning, and distance learning is more effective when it takes place in stimulating learning environments designed on constructivist principles. Rice and Wilson (1999) observe that technology can be incorporated to support many aspects of social constructivism by using collaboration in problem solving, allowing construction of knowledge by students, having learning occur in meaningful contexts, and relating learning to students' own experience. Here the technology tools include various types of simulation and strategy software, CD-ROMs, Videodiscs, multimedia/hypermedia, and telecommunications (email and the Internet) (Rice & Wilson, 1999). They argue that the major benefit to social studies teachers who integrate such technology using constructivist approaches includes the ability to obtain relevant information in the form of documents, photographs, transcripts, video, and audio clips; the capability of providing virtual experiences that otherwise would not be possible; and the opportunities for students to examine a variety of viewpoints so they can construct their own knowledge of various social studies topics (Rice & Wilson, 1999).

Resource-based learning is one of the most important characteristics in the virtual university because it is able to benefit from the resources accessible through the World Wide Web. The Australian National Council of Open and Distance Learning (NCODE) defines, resource-based learning as “an integrated set of strategies to promote student-centred learning in a mass education context, through a combination of specially designed learning resources and interactive media and technology”. According to Ryan et al. (2000), resource-based learning has become popular partly because it reflects new trends and development in the use of learning technologies, and also because it serves as an umbrella term for other terms found in the education literature, such as open learning, flexible learning, individualised learning, computer-aided learning, project-based learning, problem-based learning, student-centred learning and self-organised learning.

When the virtual university is characterised in part as resource-based learning, it is contrasted with didactic, teacher-centred learning, in which a human teacher delivers a body of subject matter that is supposed to be understood by the student (Ryan et al., 2000). Ryan et al. (2000) argue that because resource-based learning puts emphasis on the learner and the role he or she plays in achieving set goals, such as coming to understand a body of subject matter or mastering a set of skills and procedures, the orientation towards resource-based learning is fundamentally constructivist in the approach used, with emphasis on establishing dialogues designed to support constructive learning.

7.1 Progressive Implementation of Constructivist Learning

Up to now, we have been quite proud of the strength of the laboratory work incorporated within our subjects and integrated with the theory component, not only to aid student learning, but also to produce graduates with practical skills. However, organising the staffing and supervision of the laboratories, with the resultant rigid and restrictive timetable, is becoming more of a problem in a time of diminishing resources and increasing expectations. Over the years we have been making increasing use of simulations and of computer-based training, and expect this trend to accelerate, as we try to put the control of learning more and more into the hands of the students.

An early example of creating a virtual laboratory was the writing of a digital logic simulator for use in the study of computer organisation. This simulator used schematic capture at a time when most other simulators were text based, and ran under MS-DOS so that it could be used on almost any available personal computer. This program obviated the need for real laboratories in certain subjects, allowing the students to do their laboratory work in a time and place of their own choosing and submit their assignment work by floppy disk for automated testing. We have replaced this simulator by a Windows based commercial design package (Protel) which we start to use even in the first semester of the course, progressively introducing the students to the capabilities of the package as they progress through the course. This has reduced the need for formal, timetabled laboratories to a fraction of what it once was, as the students can do most of their experimentation in the virtual laboratory of the simulator, with the result that they then need less time with the real hardware to make their design work. A complete self-paced course in electronic engineering using text and computer-based simulations has been developed for second year students, funded by a UC Teaching Grant, using the PSpice analogue circuit simulator [Cheung, 1997].

Our choice of a microprocessor for illustrating aspects of computer architecture and interfacing at second year level was influenced by the quality of the development environment which was supplied free of charge by the manufacturer. As a result, not only do the students have suitable tools available to use in the real laboratories, but they are also able to do much of their laboratory work on any available computer running Windows, even to the extent of simulating much of the hardware. They are thus able to do much of what would otherwise be laboratory work, away from the laboratory. With the same end in mind, the more advanced subject on computer architecture is currently moving from tools with limited licences and restrictive platform environments to tools that are in the public domain or otherwise made freely available to the academic world, which can run on readily available hardware.

Examples of complete virtual experiments abound in the field of control systems – a field where the real system is often inaccessible to the student, or for that matter, to the university. We have instances of such experiments written in house by staff members which enable the student to write control algorithms to control, for example, a power station boiler, or even a network of power stations, and interact graphically with the controlled system. We have also found that the demonstration versions of some commercial programs, such as fuzzyTECH, come with examples which allow limited design and interaction with a simulated system – an instructive virtual laboratory for our students before they move up to building more of the virtual system themselves using tools such as Labview, or MATLAB with Simulink.

We have, in the School, experience and expertise in the development of complete computer based instruction modules, developed during the production of a CD, "Understanding the Unobservable" [Cheetham, 1995,1996]. This CD was created as a way of aiding students to understand some of the concepts of quantum mechanics, providing animations and interaction in a way only achievable with a computer-based system. This CD was created with the assistance of a CAUT grant, and provides a useful resource for students looking for a more complete coverage of quantum mechanics than we can afford to fit into the current course, as we move away from the detailed description of electronic devices and their behaviour that we used to include. As we discover other instances where instruction can be better provided in this form than by face-to-face teaching, we will not be reluctant to develop more such instruction modules.

8 THE FUTURE

The bringing together of staff from different disciplines for the course planning process, and their continued association as a result of the new School structure, has spawned increased interaction and the planning of collaborative research projects, as well as ideas for new subjects crossing traditional discipline boundaries to further the aims of the new course. In particular, a sequence of subjects on embedded systems and their interaction and programming via the .NET environment, leveraging the convergence of technologies, is under serious consideration. A feature of this new course will be the use of Web technology, mobile communications and wireless networks to enable new "virtual" approaches to teaching and learning.

A master by coursework was already under consideration at the time that planning for the bachelor course commenced, and the momentum generated by the introduction of the bachelor course has flowed over to the planning of the master course, which is now slated for introduction one semester after the introduction after the commencement of the bachelor course. The master course, currently designated "Master in Network Engineering", springs from the same notion of a need for a convergence of courses to serve the convergence of technologies. It builds to a large extent on our popular "Master of Information Technology", but incorporates subjects related to the design and management of information transmission networks, at a variety of software and hardware levels.

There is expected to be some symbiosis between these courses, as developments in one inspire developments in the other, and teaching staff get the chance to teach at a variety of levels and transfer experience from one level to another.

REFERENCES

CHEETHAM, A. D. and RAYNER, J. P. 1995. Understanding the Unobservable – A Reconstruction of First Year Quantum Phenomena. In *Proceedings of the 2nd Australian Conference on Computers in University Physics Education.* Melbourne, Australia. 1995, pp163-166.

CHEETHAM, A. D., RAYNER, J. P., and BENNET, S. 1996. *Understanding the Unobservable*. In UniServe Science News 5, 1996, p19.

CHEUNG, W. N., RAYNER, J. P., and HUANG, X., 1997. *A Self-Paced Electronics Study Program*. In 1st Asia-PacificForum on Engineering and Technology Education. Monash University, Australia.

CROCK, M. 2001 *Models for commercialization of education and training IP*. Griffith University

DUFFY, T.M. & JONASSEN, D.H. (Eds). 1992. *Constructivism and the technology of instruction: a conversation*. Hilldale: LEA

DUNN, S.L. 2001. Fuel for the future. In *USA Today*. January, 2001, pp28-29.

FLEW, T. 1998. *Hype and hope at virtual U.* In Arena Magazine. Dec, 1998, pp35-38.

FRENCH, D. 1999. Preparing for Internet-based learning. In D.French, C. Hale, C. Johnson, & G. Farr *(Eds.). Internet based learning: An Introduction for Higher Education and Business*. Virginia: Stylus. 1999.

Florida High School Evaluation (2002). The Florida High School Evaluation: 1999-2000 Year-End Report for the Orange County School Board. Tallahassee, Florida: Center for the Study of Teaching and Learning, Florida State University. Available: <URL: http://www.flvs.net/_about_us/pdf_au/fhseval_99-00.pdf.>

GATES, B. 1999. *Business @ the speed of thought. Using a digital nervous system*. Ringwood:Viking.

GREENING, T. 2000. Emerging constructivist forces in computer science education: shaping a new future? In *T.Greening (Ed.) Computer science education in the 21st century*. New York: Springer. pp47-80.

JONASSEN, D., DAVIDSON, M., COLLINS, M., CAMPBELL, J., & BANNAN HAGG, B. 1995. Constructivism and computer- mediated communication in distance education. In *The American Journal of Distance Education*. 9(2), 7-26.

LEONARD,D.C. 2000. The Web, the millennium, and the digital evolution of distance education. In *R.A. Cole (ed.) Issues in Web-based pedagogy: a critical primer* Westport: Greenwood Press.

LYMAN, B. 1999 Internet-based learning: What's in it for the adult learner? In *D.French, C. Hale, C. Johnston, & G. Farr (Eds.). Internet based learning: an introduction for higher education and business.* Virginia:Stylus. 97-117

NCODE. Quality guidelines for resource based learning report to NCODE 11 from RBL working party. Retrieved August 7, 2001 from the World Wide Web: <URL: http://cedir.uow.edu.au/NCODE/info/qual_guide.html>

PALLOFF, R. M. & PRATT, K. 2001. *Lessons from the cyberspace classroom: the realities of online teaching*. San Francisco: Jossey-Bass.

PASSERINI, K. & GRANGER, M.J. 2000. A developmental model for distance learning using the Internet. In *Computers and education*. 34(1), 1-15.

RICE, M.L. & WILSON, E.K. 1999. How technology aids constructivism in the social studies classroom. In *The Social Studies*. 90(1), 28-33

RYAN, S., SCOTT, B., FREEMAN, H., & PATEL, D. 2000. *The virtual university*. London: Kogan Page.

RUSSELL, G., AND RUSSELL, N. 1999. Cyberspace and School Education. In *Westminster Studies in Education*, 22, 7-17.

TAYLOR, J. 1999. The death of distance: The birth of the global higher education economy. In *Electronic journal of instructional science and technology (e-JIST)*. 3(1). 6-11

TUROFF, M. 1996. Costs for the development of a virtual university. Retrieved August 7, 2001 from the World Wide Web: <URL: http:eies.njit.edu/~turoff/Papers/cbdevu.html>

VRASISAS, C. 2000 Constructivism versus objectivism: Implications for interaction, course design, and evaluation in distance education. In *International Journal of Educational Telecommunication*. 6(4), 339-50.