Computer and Network Technology Education at Maximum Value and Minimum Cost

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Abstract

Rapid advances in technology place considerable demands on computer and network curriculum. A market analysis clearly demonstrated that the standard approach to teaching computer and network technology failed to meet the expectations of both students and employers. A subsequent, preliminary international market analysis endorsed this finding. Accordingly a new curriculum was designed, implemented and evaluated at Edith Cowan University. The student demand for this curriculum has always exceeded possible places and student attrition rate has been consistently very low. An independent review of one unit found: 80% would recommend this unit; 75% found the practical sessions useful; 70% found the unit relevant to their needs and 55% think this should be a compulsory unit. Significantly, this curriculum attracts students from a wider range of disciplines (Computer Engineering, Computer Science, Business IT, Multimedia etc) and also students from other universities within the state.

This portfolio of new units provides each pair of students with their own client-server network connected to the Internet, a wide range of PCs and associated equipment. Workshops include the installation and testing of: master-slave Hard disc, CD-ROM, Digital Video Disc (DVD), flat bed scanner, PC video camera, Infra-red communications link, Zip Disc etc. Other workshop exercises include establishing and testing a video conference communications link via a local area network. With nearly over two hundred students every semester the logistics associated with supporting this type of laboratory are non-trivial. Issues include: initial equipment cost, student safety, damage to equipment and technical support, This paper presents details of how this new curriculum was designed and implemented at a minimum cost.

1. Introduction

Reports such as the 1991 ACM/IEEE-CS *Computing Curricula* [1] provide the foundations of computer science curriculum world wide and set benchmarks for accreditation by professional bodies. The computer science degree at Edith Cowan University (ECU) is level one accredited by the Australian Computer Society (ACS). According to the 1991 ACM/IEEE-CS report, “The outcome expected for students should drive the curriculum planning". Within Western Australia an exploratory market audit was conducted of a wide range of industrial and commercial companies. This was complemented by a further detailed analysis of the IT department of a state wide rail company. From this survey a set of guidelines were developed for the type of skills expected of computer science graduates entering the field of computer and network support. Using the criteria developed a random selection of ten, final year ECU computer science undergraduates were interviewed from a graduating population of approximately one hundred. According to Maj:

> "It was found that none of these students could perform first line maintenance on a Personal Computer (PC) to a professional standard with due regard to safety, both to themselves and the equipment. Neither could they install communication cards, cables and network operating system or manage a population of networked PCs to an acceptable commercial standard without further extensive training. It is noteworthy that none of the students interviewed had ever opened a PC. It is significant that all those interviewed for this study had successfully completed all the units on computer architecture and communication engineering" [2].

The computer architecture and communication engineering units were: Computer Technology, Microprocessors, Data Communication & Computer Networks. These units follow the standard approach taken by most universities. The Computer Technology unit introduces students to computer systems and hardware i.e. number codes, assembly language (Motorola 6800), machine architecture etc. The Microprocessor unit is a detailed examination of microprocessor technology and an in-depth treatment of assembly language (Intel). The Data Communication & Computer Networks unit provides an understanding of the physical and logical elements of data communications with a detailed discussion of the ISO OSI model. Furthermore, interviews conducted with five ECU graduates employed in computer and network support clearly indicated that they were, to a large degree, self-taught in many of the skills they needed to perform their job. Preliminary investigations indicated a similar situation with computer science graduates from other universities within Western Australia. This problem is exacerbated not only by the constant and rapid changes in technology but also the requirement to teach technology to students from a wide range of discipline such as multimedia, e-commerce etc. The authors therefore attempted to find an alternative approach to teaching introductory computer and network technology. According to Campus Leaders:

> "the predominant reason why they (students) have gone to university was to get skills, knowledge and a qualification that would assist them in either gaining employment or enhancing their prospects for promotion or a more rewarding job" [3].

Other countries similarly have professional accreditation. In the United Kingdom (UK) the British Computer (BCS) accredits university courses and has an internationally recognized examination scheme in two parts with Part II at the level of a UK honors degree in computing. The initial ECU student questionnaire, first used in 1993, was also conducted in 1999 at two universities in the UK. A similar study is currently being undertaken in Sweden. The first university has well established degree programs and is fully BCS accredited. The second university recently redesigned their IT awards, some of which are now BCS accredited. The degree programs at the first university offer students the opportunity to examine a PC in the first year as part of a module in Computer Organization. However they never take a PC apart. Students are taught network modeling, design and management but they do not physically construct networks. The results clearly demonstrate that students lacked knowledge about PC technology and the basic skills need to operate on computer and network equipment in a commercial environment. This is despite the fact that most students thought such knowledge would be beneficial. The survey indicated that any practical knowledge students have of hardware is largely a result of experience outside the course. At the second university the results demonstrate that these students had a broad, hobbyist's understanding of the PC but no knowledge of health and safety law. Significantly, the students interviewed identified that their skills and knowledge of PCs and networks came from self-study or employment, not from courses at university. Again student responses indicated that such knowledge would be useful. We therefore examined developments in computer and network technology curriculum.

2. Computer and Network Technology Curriculum

The problems associated with teaching computer technology are not new. Units in microcomputer systems are fundamentally important to students [3, 4]. These address issues that include: computer organization, memory systems, assembly language, digital logic, interrupt handling, I/O and interfaces. Mainstream computer science education is well supported by journal articles on various aspects of re-programmable hardware for educational purposes [5] and assembly language [6]. Simulation has proved to be a very useful tool [7, 8, 9]. Reid used laboratory workstations to allow undergraduate students to "build a complete, functioning computer - in simulation" [10]. The simulation is so complete that it:

> "extends down to the gate and signal levels, with effective modeling of delays and transitions, so reasonable assurance of the validity of the designs can be achieved. The computers constructed in this laboratory are complete with peripheral equipment including tapes and discs, and the students furnish a rudimentary operating system" [10].

Pilgrim [10] took an alternative approach in which a very small computer was designed in class and bread-boarded in the laboratory by students using small and medium scale TTL integrated circuits. Thereby, according to Pilgrim, providing students with the "knowledge and experience in the design, testing and integration of hardware and software for a small computer system" [11]. According to Parker and Drexel simulation is a preferred approach because:

> "In the past we used separate and usually unrelated, bread-boarding labs to demonstrate basic system elements: decoders, multiplexers, sequential logic etc. However, students often do not see the big picture" [12].

The difficulty of providing a suitable pedagogical framework is further illustrated by Coe and Williams:

> "In trying to understand the detailed operation of the computer, the student must consider the constantly changing state of its individual components. One natural way to represent this state information is by means of components. However even for the simplest uni-processor the set of data to be conveyed by such means is very large and subject to rapid change". [13]

And further that:

> "This presents the scientist with a problem – how to represent a large, ever changing set of state information with sufficiently fine time resolution of be useful" [13]

Coe et al address this problem by means of simulation. Barnett 14 suggests that standard computer architecture is too complex for introductory courses and that "One alternative is to define a simple computer with a limited instruction set and use this computer as an example"

Similarly the problems with teaching network technology are not new and various approaches have been employed. Primarily software approaches have been advocated by [15, 16, 17, 18.]. The dominance of the TCP/IP standard being addressed by [19, 20]. Advocates of simulation as a primary tool for curriculum design include [21, 22, 23] . According to Engel simulations and demonstrations, though valuable, do not provide students with procedural skills such as how to actually install, maintain and manage a network [24].

However, it is possible to consider the PC and network technology from a different perspective. The PC is now a (relatively) low cost consumer item. This has been possible due to design and manufacturing changes that include: Assembly Level Manufacturing (ALM), Application Specific Integrated Circuits (ASICs) and Surface Mounted Technology (SMT). The result is PCs with a standard architecture and modular construction – so simple that high school students take them apart. However, traditionally computer technology education is typically based on digital techniques, small scale integration IC's, Karnaugh maps, assembly language programming etc. Operation on PCs at this level simply does not exist any more within the field of computer and network support. Valuable though simulation and breadboarding may be a typical PC support environment demands other knowledge and skills that include: upgrading PCs, fault identification and correction procedures, safety, ability to recognize different system architectures etc. Simulation provides no experience of practical problems such as inserting a new input/output card into a PC and the associated skills that are needed.

3. Procedural Skills – Conceptual Knowledge

The authors submit that that despite interest from students the standard curriculum in computer and network technology does not provide students with the opportunity to acquire the necessary skills recognized as either relevant to their needs or those of potential employers [25]. This opportunity to develop technical expertise is an enhancement of theoretical knowledge. According to Cervero: "the popular wisdom among practicing professionals is that the knowledge they acquire from practice is far more useful than what they acquire from more formal types of education" [26]. Cervero further argues that the "goal of professional practice is wise action" and that "knowledge acquired from practice is necessary to achieve this goal" [26]. Both conceptual and procedural knowledge are necessary for professional practice. Procedural knowledge is knowledge *how* to do something. The 1991 ACM/IEE-CS report states that, "undergraduate programs should prepare students to apply their knowledge to specific, constrained problems and produce solutions" [1]. A good case can therefore be made to provide students with the opportunity to perform workshop exercises such installing and maintaining networked PCs in an environment that mimics standard commercial/industrial practices and is more directly relevant to student needs.

4. Curriculum Design – Computer Technology

At ECU a new curriculum was designed consisting of four units – Computer Installation & Maintenance (CIM) and Network Installation & Maintenance (NIM) both prerequisites to Computer Systems Management (CSM) and Network Design & Management (NDM). The units CIM and NIM were introduced first. The success of these two units led to the introduction of the other two units.

The unit CIM attempts provides a practical, inter-disciplinary, problem oriented approach. Rather then lowering academic standards Professor Lowe, as cited by Armitage, argues, "the complexity of the real world is more intellectually taxing than living in imaginary worlds of friction-less planes, perfectly free markets or rational policy analysis" [27]. There are no unit pre-requisites for the CIM unit, hence one of the main problems is to control complexity as PC architecture can become complex very quickly. Accordingly a systems engineering approach is employed ie. a top down, hierarchical, modular analysis. According to Scragg:

> "most (perhaps all) first courses in computer hardware are created "upside down" - both pedagogically and pragmatically'. This has the consequence that 'Pedagogically, this approach provides no "cognitive hooks" , which might enable students to relate new material to that of previous courses - until the semester is almost complete" [28].

Accordingly Scragg recommends a top down approach starting with material already familiar to students and then working towards less familiar models. In contrast to traditional units in computer architecture/technology the unit CIM does not include digital techniques (combinatorial and sequential logic), details of processor architecture at register level or assembly language programming.

Rather the PC is considered as a set of inter-related modules each of which is then addressed in detail appropriate to a first level unit. In particular the PC is treated as a 'whole' with detail carefully controlled on a 'need to know' basis. For example, the lectures on memory devices address the principles of operation of primary and secondary memory. Disc drive operation is considered along with typical performance figures and the advantages/disadvantages of the different types of controller (IDE, EIDE, SCSI). This is complemented by the associated workshops with a working demonstration of a disassembled but operational hard disc drive. Furthermore, in the workshops students are required to perform experiments that include: installation of a second floppy disc drive; addition of a second (slave) Integrated Drive Electronics (IDE) hard disc drive; upgrading from an Industry Standard Architecture (ISA) input/output card to a PCI Local Bus etc. This is complemented by experiments in fault diagnosis, correction and management. All operations are at the module rather than the component level.

Twenty-five IBM model 50z PCs were selected for two reasons. Firstly cost, they were decommissioned and obtained at minimum cost. Secondly, even though they are about 10 years old, they are highly modularised with only two connecting wires in the entire machine - it is difficult to plug modules in the wrong way. They have, to date, proved to be an ideal 'trauma free' PC for this introductory unit thereby allowing complexity to be introduced in a safe and controlled manner. It is essential to be systematic with respect to workshop procedures; for example, always use an 'earth' strap and only change one variable at a time. Observation skills are needed; for example, never disassemble a device that you cannot reassemble and if necessary take notes. Safe working practices are mandatory. Accordingly a simple mnemonic was devised - 'Systematic Observation and Safety' (SOS). Experience to date has shown that all students could disassemble an IBM 50z, however about one third of all workshop groups could not initially successfully reassemble a PC. Quite simply they did not understand the principles of systematic observation. In this case they failed to ensure the edge connectors were properly seated.

Rather than consider the technical detail of one particular type of PC architecture, a range of PC architectures are used thereby ensuring vendor independent and generic maintenance skills. The principles of computer operation along with an emphasis on the skills associated with installation, fault diagnosis etc. provides skills that are readily portable between different PC architectures. Given the rapid changes in technology this emphasis on generic skills is a non-trivial issue.

It should also be noted that the students who claimed to have prior experience in this field damaged more equipment than the novices. Clearly 'self evaluation' of skills is inadequate. It was found that students must be given the opportunity to repeat many of the tasks in order to acquire the necessary skills. According to Cervero "procedural knowledge underlies skilled performance, and that procedural knowledge is acquired through practice" [26] .

Commercial equipment is not designed for repeated disassembly and reassembly. Even with the most rigorous workshop practices, equipment was damaged. We submit that this can only be accepted as a natural consequence and budgeted for accordingly. The use of decommissioned equipment significantly minimizes this expense. After satisfactorily completing the basics, students were then required to work on a range of different and more complex PC's with extensive and complex cabling prior to using new equipment. A range of PC architectures were used: Intel (286, 386, 486) based Micro Channel Architecture (MCA), Industry Standard Architecture (ISA), Video Electronic Standards Association (VESA) Local Bus and Peripheral Components Interface (PCI).

An essential feature of the workshops is that not only are the PCs disassembled but also some experiments employ 'live' testing. It should be noted that even though two earth leakage detection circuits were installed (10 and 20mA) in the workshop such circuits may afford no protection to the individual when a PC is mistreated. Hence, throughout the workshops the PC was treated as a potentially dangerous device. In the final analysis no one can ensure that an open PC is not in a dangerous condition and the potential for fatal accidents by electrocution must always be considered. Accordingly, high tension devices, the VDU and power supply, are never opened.

One of the main problems that we have faced is that students are accustomed to ‘soft systems’ in which it is always possible to re-compile or use the ‘undo’ button in order to correct a mistake. This type of work is, however, very unforgiving and accordingly a fundamentally different approach was needed and must be taught. One wrong connection made during a live experiment can destroy a motherboard. It should be noted that all workshops were supervised.

All the IBM model 50z PC’s were modified with ‘switchable faults’, designed and constructed ‘in house’, thereby allowing the controlled selection and de-selection of known fault conditions. Using these switches, discretely placed on the motherboard, it was possible to selectively enable a variety of fault conditions affecting : individual VDU guns (red, green and blue), horizontal and vertical synchronization, BIOS, keyboard, fan, floppy disc drive motor and index pulse.

The CIM unit is followed by a second unit, Computer System Management (CSM), in which students are introduced to more advanced technologies. Accordingly workshops include installation and testing of: Digital Video Disc (DVD), flat bed scanner, PC video camera, Infra-red communications link, Zip Disc etc. Other workshop exercises include establishing and testing a video conference communications link via a local area network. The workshops are based on typical Multimedia applications. It must be stressed that CIM is a pre-requisite to CSM. The equipment used in CSM is expensive, ‘state of the art’ technology. The prerequisite link helps to ensure that students are able to correctly handle expensive equipment in a safe manner. We suggest that even with the higher level units there is no requirement to teach electronics or digital techniques.

5. Computer Design – Network Technology

Novell have internationally recognized professional development program - the Novell Certified Network Engineer (CNE) which consists of a number of courses. The unit NIM is based on three courses from the CNE program i.e. Administration, Advanced Administration and Networking Technologies [29]. The course Administration is intended for NetWare systems administrators responsible for the day-to-day operational management of the network such as basic network services, login scripts, file system management etc. Advanced Administration introduces more complex tasks that include planning the directory structure, tune performance and troubleshooting. The course Networking Technologies provides the basic concepts of network technology i.e. transmission media, OSI model etc. It must be stressed that the NIM unit is not simply a collection of three CNE courses. Rather the NIM unit uses Novell as the target Network Operating System for workshop exercises in conjunction with more theoretical lecture material. In the NIM unit workshops each pair of students are allocated their own client-server Local Area Network (LAN). At the conclusion of the NIM unit students are able to take three Novell courses. To study for these three Novell courses commercially would cost approximately $A3,000. Students can therefore obtain commercial certification for university fees. The subsequent unit NDM is NT based and includes topics such as proxy server, DNS server, RAS server etc.

6. Laboratory Design and Technical Support

A dedicated laboratory for the units CIM and NIM was designed, constructed and equipped at an initial cost of $A35,000. The extensive use of decommissioned equipment and the in-house development of switch faults significantly helped to reduce the cost. With this budget it was possible to provide each of the 10 workplaces within the laboratory with three different types of PC of increasing cost and complexity. For maintenance purposes it was found essential to have at least 15 of each type of PC. In addition to this class sets of equipment were provided (Network cards, CDROMs, PCI video cards etc). The CIM laboratory therefore consisted of 45 different PCs. For the NIM unit each workplace consists of a client (Intel 486), a server (Intel 486) and a ten-port hub i.e. a self-contained network. The cabling in the laboratory (Category 5, Unshielded Twisted Pair) allows all the hubs to be connected together to a switch or hub, located in a patch panel, and hence connected to the worldwide web with protection by means of a firewall.

At the conclusion of each two-hour workshop all the equipment must be checked and where necessary reconfigured. Experience dictates that two hours of support is needed between successive CIM workshops. For the NIM unit only one hour of technical support is needed between successive workshops. However experience has shown it is advantageous to allow two hours for maintenance hence allowing for the occasional, catastrophic failure of equipment. For all other units at ECU only the first hour of each workshop is supervised, for the second hour students are guaranteed access to the laboratory – but no supervison. During the semester they have unrestricted access to any vacant laboratories 24hours a day, 7 days a week. Given the nature of the CIM, NIM units workshop access is restricted to the allocated workshop periods, all of which are fully supervised. Prior to the start of each workshop each pair of students must complete and sign a checklist of equipment. Students are not permitted to leave the workshop until the equipment is returned.

The number of students for CIM and NIM is restricted to eighty for each unit. This allows four workshops per unit with two students per workplace. The CIM lecture is given Monday evening (5-7pm) followed by a two-hour workshop (7-9pm). There are three workshops on the Tuesday (9-11am, 1-3pm and 5-7pm). The NIM lecture is given on Wednesday evening (5-7pm) followed by a two-hour workshop (7-9pm). There are three associated workshops on Thursday (9-11am, 1-3pm and 5-7pm). This arrangement allows the whole of Wednesday to remove the CIM equipment and replace it with the NIM equipment. Monday and Friday are used for change over and development work. Experience had clearly demonstrated that no other arrangements are possible, furthermore it is essential to have an adequate, secure and convenient storage location. The CIM, NIM curriculum is supported by a technician for 2 days full-time equivalent. The evening classes provide the opportunity for part-time students to attend these units.

The success of the curriculum was such that two other units were introduced (CSM and NDM). Accordingly another dedicated laboratory was designed and constructed at a cost of $A60,000 and operates on similar principles to the CIM/NIM laboratory. However in this laboratory students are provided with 'state of the art' and hence expensive equipment.

Equipment must continually be replaced. Strict workshop practices minimizes but does not prevent damage and general 'wear and tear'. Given the rate of PC development many companies decommission equipment which typically can be obtained at no cost. The main criteria for selection is that for a given type of PC it is essential to have at least 15 identical machines thereby sufficient for a class set of PCs with spares. Both laboratories can be maintained with a budget of approximately $A5,000 per annum. This is sufficient to replace items such as network cards etc.

7. Health & Safety

Arguably the most important theme in the CIM unit is Health and Safety - employees and employers have non-delegable legal responsibilities. The principles of Health & Safety are introduced at the start of the unit. The first workshop was concerned entirely with workshop practice and students were required to read both the university and workshop regulations - it was emphasized that misconduct would not be tolerated. Misconduct is taken to include failure to observe good workshop practice. Compulsory attendance at the first lecture and workshop were verified by a signed declaration. Failure to comply being an automatic disqualification from continuing the unit. Many students have little or no knowledge of legal issues. The unit therefore includes a lecture on law and technology in order to fully appreciate the significance and importance of Health & Safety legislation. After a brief overview of the legal system, the tort of negligence is addressed with reference to negligent misstatement. However, particular emphasis is placed on negligent acts and the associated Duty of Care and Standard of Care of both employee and employer. The examination has a compulsory question on health and safety worth 20%.

8. Results

The units CIM and NIM were piloted in semester 1, 1996. The majority of students who attended the unit CIM had never taken apart a PC - quite simply they were too intimidated by the complexity of a PC and were concerned about the consequences of making a mistake. Typical comments were “I have never opened a PC before. I always wanted too but I was too frightened”. The minority who had did so without knowledge of and due regard to good workshop practice to ensure safety both to themselves and the equipment. At the conclusion of the unit CIM students had the confidence and ability to disassemble, upgrade and perform first line maintenance on a PC to a professionally acceptable standard - they knew how to approach the problem, what you must always do and what you must never do. Whilst lacking in experience that comes with time, they could operate with safety in the role of computer support and solve the many of the more common problems. The majority of students who attended the unit NIM had never installed a LAN. At the conclusion of this unit students were able to install and manage a simple network. The initial quota of 100 students for the unit CIM was exceeded with 118 students enrolling and even then demand exceeding possible places. The student attrition rate was 8.5% with a subsequent unit failure rate of less than 10%. Since they were introduced both units have always been oversubscribed, had a very low attrition rate, attracted students from other faculties and also other universities by means of cross-institutional enrolment.

An independent unit review of the CIM unit found: 80% would recommend this unit; 75% found the practical sessions useful; 70% found the unit relevant to their needs and 55% think this should be a compulsory unit. The majority of students enrolled were computer science majors with many in their final year. Three students were enrolled in an MSc in Computer Science. There were students from a wide range of disciplines and significantly, some final year B.Eng. (Computer Systems Engineering) students.

An educational expert independently evaluated the unit CIM in order to assess students' perceptions of the unit, the educational approach taken and the educational value of the unit. Interviews were conducted with students at the start and end of the course. Results presented here are from interviews conducted at the end of the course [30]. Five students, chosen at random, were interviewed. Interviews were semi-structured consisting of a number of closed and open ended questions and respondents were encouraged to comment on any positive or negative aspect of the course and its effect on their learning. Students' responses were grouped into common themes, reported below and substantiated by quotes. All students perceived the unit as being very valuable. They thought it was "excellent, really good" and especially liked the "hands on stuff" and the "logical, sequential presentation of content". One student thought that "the practical side was really good and I learnt a lot". A fourth year engineering student described the unit as "very helpful" explaining that all the rest of his course was theoretical, with nothing practical dealing with the "components with which I have to work". He said, "I never see the component in the whole four years of my course" so to actually work with the components "was helpful to my understanding". He stated that this unit should be in first year "to help students visualise what they are working with". A business student described it as "a very good unit" saying "it taught me many, many things I did not know despite my background in information processing". Another student with a poor background in computing also liked the unit saying "It's a great unit, I liked it very much" and felt that he would "benefit very greatly from it". One student appreciated the way in which this unit effectively "demystified the machine and took me behind the scenes" and "gave an understanding of how computers work". All students stated that their understanding of computers and computing was increased by this unit. According to Maj,

> "Based on the above interviews it can be stated that this unit (CIM): is perceived as very valuable by students from different disciplines; supports learning in other units; increases students' understanding of computers and computing; generates a demand for further curriculum in this field; and is about right in terms of difficulty" [30].

9. Digital Techniques

According to the report of the 1991 ACM/IEE-CS Joint Curriculum Task Force report computer science curriculum includes: digital logic and systems, machine level representation of data, assembly level machine organization, memory system organization and architecture, interfacing and communications, and alternative architectures [1]. The authors do not suggest that the bandwidth node model should replace the teaching of this traditional computer technology curriculum. Rather, it may serve as a useful introduction that provides both interesting and useful skills. This point is reinforced by Ramsden:

> "Material should preferably be ordered in such a way that it proceeds from common-sense and everyday experiences to abstractions and then back again to the application of theoretical knowledge in practice" [31].

10. Conclusions

PCs now play a dominant role in commerce, industry and entertainment. In this context the standard computer and network technology curriculum designed for computer engineering and computer science students is in danger of becoming perceived as increasingly irrelevant – both by students and potential employers. This paper presents the results of implementing one possible solution to providing an introductory computer and network technology curriculum suitable not only for students from other disciplines but also as a basis for Engineering and Computer Science majors. The workshops of this new curriculum provide students with the opportunity to perform workshop exercises such installing and maintaining networked PCs in an environment that mimics standard commercial/industrial practices and is more directly relevant to student needs. Though more expensive than more traditional workshops it is still possible to be done in a cost-effective manner. The success of this new curriculum is such that since the first two units were introduced both units have always been oversubscribed, had a very low attrition rate, attracted students from other faculties and also other universities by means of cross-institutional enrolment. Furthermore demand has been such that two other units have recently been introduced with the expectation of the curriculum being expanded even further.

Biliograhy

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David Veal received his honours degree in Theoretical Physics from the University of York in England. He lecturered in Physics at South Devon college UK for 10 years. He now lives in Westrn Australia where he has taught Computing and Physics at high school level. He is studying for his PhD in Computing Science at ECU in Perth, Western Australia and is investigating competency based techniques in Computing Science as well as the modeling of computers to aid student understanding.

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Dr S P Maj is a recognized authority in the field of industrial and scientific information systems integration and management. He is the author of a text book, '*The Use of Computers in Laboratory Automation*', which was commissioned by the Royal Society of Chemistry (UK). His first book, '*Language Independent Design Methodology - an introduction*', was commissioned by the National Computing Center (NCC). Dr S P Maj has organized, chaired and been invited to speak at many international conferences at the highest level. He has also served on many national and international committees and was on the editorial board of two international journals concerned with the advancement of science and technology. As Deputy Chairman and Treasurer of the *Institute of Instrumentation and Control Australia (IICA*) educational sub-committee he was responsible for successfully designing, in less than two years a new, practical degree in *Instrumentation and Control* to meet the needs of the process industries. This is the first degree of its kind in Australia with the first intake in 1996. It should be recognized that this was a major industry driven initiative.