Preparing for the Future of information Technology: a Degree that encourages cognitive and perceptual Development

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ABSTRACT: *University curricula and teaching methods in information and communication technology (ICT) degrees such as computer science and information systems remain conservative, despite the rapid changes in the underlying disciplines. This is all the more surprising given the number of indicators that current ICT education should be changing. These indicators include an ICT industry which is maturing and requiring increasingly multiskilled well rounded employees; a widespread acknowledgement of a 'skills gaps' which current graduates need to bridge on entering the workforce; the pace of change which makes maintaining up-to-date curricula difficult yet which has fostered a vast array of authoritative open Web resources maintained by practitioners; and the falling participation rates of females.*

We have designed a novel information technology program which seeks to adapt existing ICT education practices and content to the new environment, by changing the delivery method to a problem based approach and by emphasising creative and entrepreneurial development. Problem Based Learning motivates learning by situating it in real world contexts, and focuses on developing information search and problem solving processes. The inclusion of creative design and communications courses in the program builds cognitive and perceptual skills, in keeping with this century's requirements for a multiskilled workforce. The aims and design process of the degree are described, along with reactions from staff and the first intake of students.

1 INTRODUCTION

The environment in which the information and communication technologies (ICT) industry operates has historically been one of swings in fortune. Lately, talk of ICT skills shortages has mutated to "ICT skills gaps" (eg. BCS 2002). High unemployment rates in the sector have made OECD governments retreat from measures such as training inducements or relaxed immigration regulations introduced to increase the ICT workforce. While the increasing dependence of all societies and economies on ICT means that the current downturn in the sector is expected to reverse once again to boom, there are structural shifts taking place. Amongst these are globalisation, which affects every industry sector and which has seen a trend to source routine development as well as system management and maintenance from the best-value supplier regardless of their location (eg. McCue 2004).

As it matures in a volatile environment, the ICT industry is calling for a multiskilled and mobile workforce whose participants can move in and out of the sector according to the cycles in demand. Some specialist skills and knowledge remain in undersupply worldwide because the workforce has not been able to undertake technical retraining fast enough, or because of particular requirements of the application domain (Nakayama & Sutcliffe 2001). Such trends mean that, in mid-cost countries such as Australia, education and training in IT must increasingly be targeted at producing graduates fitted for non-routine tasks and draw on an ever-changing toolbox of technical skills (eg. Davis, Siau and Dhenuvakonda 2003).

The so-called core bodies of knowledge which guide much of the IT curricula development at Universities round the world are those for Computer Science (CS), Software Engineering (SE) and

Information Systems (IS) promulgated by the Joint Task Force of the Computer Society of the Institute for Electrical and Electronic Engineers (IEEE-CS) and the Association for Computing Machinery (ACM). (The IS curricula frameworks are also supported by the Association for Information Systems (AIS).)

The core body is comprised of the fundamental skills and knowledge which are broadly agreed to be required of every graduate in the disciplinary area. This core is extended in a variety of ways, depending on the specialisation, and is understood to be continually open to revision to accommodate the pace of change in the underlying technologies. This leads to debate around specific technical content (CC 2001). A perennial debate also surrounds the skills-versus-education dilemma, because a skills emphasis may produce more industry-ready graduates but may be poorer at equipping them for self-directed learning in the future in which technology will inevitably change. There is also a long standing debate –notably between the disciplines-- on the relative emphasis on hard versus soft skills.

Despite this level of reflection and debate, the curricula of all three disciplines remain conservative. Thus, the only significant change between the 1993 and 2001 core bodies of knowledge developed by the IEEE/ACM for computer science was acknowledgement of the new role of networking and to a lesser extent of multimedia and information management. The parts of the curriculum concerning development of personal qualities such as creativity and communication skills, or of knowledge of organisational behaviour or project management, were not substantially altered.

Delivery mechanism as well as content remain conservative. Pedagogy changes were noted in the IEEE/ACM report in terms of supporting technology such as computer projection and laboratories. The use of projects, especially in final year, is generally seen to be an essential part of ICT education, drawing together learning in other courses and helping to build team work and project management skills. However, the use of problem based learning (PBL) as the delivery mechanism of courses or programs has made little inroad into ICT education.

If graduates are to have the ability to multiskill, to be creative, to be self directed and to work in teams as required in the maturing ICT workforce, then curricula design and teaching methods need to explicitly develop and enhance qualities such as student centred learning, creativity, entrepreneurship and people skills. These are arguably harder to transfer than are technical skills. The full range of technical knowledge and skills, as well as these non-technical qualities, must be acquired by the student in the same timeframe as before, because in the current climate there is usually a constant level of support for ICT training from government or industry. This means the student must learn more in the same time, and hence work harder or smarter.

The emphasis on learning-to-learn, on team work, on practical problem-solving and holistic learning commonly associated with PBL all would seem to address the requirements of industry, and to be compatible with the graduate profile targeted by most Universities. Additionally, the large number of repositories maintained by practitioners on the Web (eg Snoke and Underwood 2001), form accessible authorative information resources that because of the rapid change of technology are often more useful and up-to-date than the conventional text book. Finally, PBL has generally been shown to motivate students more than conventional pedagogical approaches (Vernon & Blake 1993).

2 PROBLEM BASED LEARNING

The 'medical school' curriculum introduced at the McMasters University Medical School saw small groups of students asked to explore problem situations, with the objective of not only determining a solution, but of exploring the problem definition itself, the gaps in their relevant personal knowledge and skill sets, and the means by which they could acquire pertinent information to assist them to resolve or manage the problem situation (Barrows & Tamblyn 1980, Barrows 1986). As a result, it was argued, students would be better prepared to cope with the ill-structured problems encountered in subsequent professional practice than they would be under the traditional-lecture based, memorisation oriented learning regime (Barrows 1990).

While PBL can be found in may different forms, there are five generally agreed principles. Firstly, and central to any definition, is the contexualisation of learning in real world settings. A second principle is the multi disciplinary nature of knowledge, which breaks down "silos" of learning that follow historical organisational structures in a University more than any pedagogical priority. A third principle is an emphasis on thinking skills, that is, on going beyond the content or processes of the particular professional domain, to learning about cognition and the acquisition of skills. Related to this is a emphasis on self directed learning, which puts the student proactively in charge of their own learning outcomes. The last principle is the use of groups as a more effective problem solving unit than the individual, with all that group work entails.

The research evidence tends to conclude that this style of learning can produce favourable results. For instance, two independent meta-analyses of research findings on PBL implementations in medical schools over the period 1970 – 1992 (Albanese & Mitchell 1993, Vernon & Blake 1993) both conclude that PBL was instrumental in higher student satisfaction, clinical performance, clinical knowledge, and aspects of student study behaviour (e.g. self-directed study), relative to traditional methods. An identified risk within the PBL approach is of lower levels of content knowledge and the associated cognitive framework around which students need to attach future learning.

The last decade has witnessed many implementations of variations of PBL, in many countries and many professionally-based disciplines. An early example in IT programs in Australia was the Bachelor of Informatics at Griffith University (Abel, Margeston & Saauer 1987). This was designed around a focal question, which was decomposed into several thematic problems which in turn were posed as central questions, each associated with a course. Griffith's current B Information Technology continues to have a strong practical flavour, although the original experiment was not continued for reasons that have not been documented. At the University of Queensland, a novel Bachelor of Information Environments program was developed (Docherty et al 2001). The degree combines standard computer science studies with design courses and integrative studio-based projects which require interactive problem solving.

An introductory full year computer science course using PBL has been successfully operating at the University of Sydney since 1996 (Kay & Kummerfeld 1998), and has been refined with experience and with student reaction over the years. The use of PBL within the Bachelor of Computer Science has not been extended to more courses at this University. Bentley, Lowry & Sandy (1999) describe the experimental PBL delivery of an information systems course at Victoria University of Technology, with a control group taught by traditional modes of instruction. The results of this experiment have not yet been published.

In general, PBL studies have tended to turn from generalised evangelical "proof of concept" examinations to more specific, critical, discipline centred research incorporating modern learning theories (Boud & Feletti 1997) and new perspectives, such as the accrued personal experiences available in PBL (Savin-Baden 2000). It is recognized that the change to a PBL teaching approach requires a paradigm shift for those participating in the process (Camp 1996). To be effective, comprehensive staff development is needed, with support to avoid problems of staff disillusionment (King 1999). While the reasons for discontinuation of excursions into PBL are often hard to trace because these are rarely documented, they appear anecdotally to be linked to movements of staff who had been the original champions of the new teaching approach. These "failures" may increase staff resistance to PBL, with contra arguments being advanced on pedagogical grounds, presumed student preference for structured learning, and resourcing (PBL is claimed to be more expensive than other teaching methods).

The (indirect) lesson to be drawn from experience and evaluations is that careful planning and preparation within a framework of explicitly defined objectives and terminology are essential if learning is to be embedded within the professional practice of a discipline. While recent evaluations suggest placing the subject content in a problem based context can enrich and reinforce declarative knowledge, a balance is needed between the PBL student self-directed learning, on the one hand, and the learning objectives for the students as seen by academic staff and the profession, on the other.

3 DESIGN OF A BACHELOR OF INFORMATION TECHNOLOGY

The University of Newcastle has an international leadership in PBL, based initially on a relatively early implementation in a medical degree, designed in the 1970s. PBL had been successfully adopted in architecture, law and nursing programs. There had, however, been no large-scale attempt to adopt this style of teaching in engineering, business or science. The University had had a teaching and learning unit[1] with internationally acknowledged PBL expertise.

[1] This unit was disbanded at the time of implementation, but the expertise was still available though consultancy.

In 2002, the University decided to offer a new Bachelor of Information Technology (BIT) for an intake at the first year level in2003. It was to be a three year degree with an optional Honours year, as is usual in such degrees in Australia. The BIT was to be the focus of IT teaching in a new multidisciplinary School of Design, Communication and IT, in a newly formed Faculty of Science and IT. The Communication and Design disciplines each taught an eponymous degree in which many courses were project based or so called "studio based", ie. characterised by group work on a few large projects and having a small or zero percentage of student time spent on the course in lectures. The use of PBL was therefore encouraged when the degree development was approved. It was also expected that the new degree would exploit the structural asset provided by the grouping of Design, Communication and IT, because the notions of "client", "audience" and "user" which the three professions target are in fact merging. An initial plan to use interviews as a selection mechanism was not supported by the University.

A steering committee chaired at the Pro Vice Chancellor level was formed to oversee the development. Representatives were drawn from large and small IT firms, from local IT industry consortia and the IT professional association. The academic representatives covered information systems, software engineering, and computer science disciplines. The designer of the only extant PBL IT-related degree in Australia -- at the University of Queensland-- and the PBL consultant who had previously led the University's learning unit were also on the committee. Finally, there was a representative from a multimedia professional association and a Professor of Design.

The Steering group guided the formulation of the graduate profile -- that is, the characterisation of the ideal graduate of the degree – and advised on the number and broad nature of the compulsory courses and of the majors. This included endorsing the plan to include introductory design and communications courses in the compulsory set.

The graduate that the Steering Committee envisaged the BIT to was one who is

1. Technically expert in information technologies with an emphasis on user-centric, information-centric and net-centric computing
2. Understanding of the operation and constraints of contemporary enterprises
3. Creative, inventive and a problem solver
4. A good communicator, leader and team player
5. Entrepreneurial, professional, adaptable and socially responsible.

This profile has elements common to any graduate profile, because most Universities desire similar generic qualities in their graduates. Distinctive elements of the profile are the triangular technological focus of (1) combined with the contextual understanding of (2), and the fact that the program is designed to explicitly develop each of the qualities in (3-5). While qualities such as inventiveness, creativity and so on feature in many graduate profiles, these are usually left to be implicitly developed while the curriculum concentrates on content, or are assumed to be developed in a single project course.

The compulsory part of the program was to ensure the outcomes required by the target profile; was to cover the core body of knowledge required for professional accreditation by the Australian Computer Society; was to be taught in PBL2; and was to cover as much as possible of the core knowledge in the IEEE/ACM guidelines for a computing professional3. The University policy is to minimise the compulsory part of any program to maximise student choice, and this minimum was agreed by the steering committee to be half of the 24 courses in the three year program.

As is usual in PBL, knowledge and skills start from a broad base, with depth built over repeated visits to material, rather than the depth-then-breadth approach traditionally followed. The four compulsory courses in the recommended first year program include creative design in the first semester, as this course encourages students from the outset to think about perception, the design process, and their own creativity. In this first semester, students are introduced to the intent and nature of PBL and group work. Over the first year, they are introduced to project management, systems analysis, database design and implementation, object oriented programming, n-layer architectures and networks. All of this is in the context of organisations and the interaction between government, society and technology.

[2] After the Steering Committee was disbanded, a conventional introductory programming course was introduced into the compulsory set and the other courses adjusted accordingly, due to organisational politics. Programming is to IT what anatomy is to medicine, and the PBL teaching of anatomy in medicine has remained controversial (ref).

[3] Operating systems, discrete mathematics and algorithms were not to be covered to the depth specified in the computer science core.

In second year students study human communication theory and the role of government and media in shaping opinion in a communications course. They look at the increasingly important area of justifying and monitoring investment in information technology, including both mainstream and speculative projects. Technically they are introduced to operating systems and revisit the technical areas in three other compulsory 2nd year courses. Two of the three compulsory third year courses are used primarily to deepen technical knowledge and skills. The third concerns professional development and and marketing of IT artefacts and services, including consultancy services, creative thinking and risk taking.

In each semester, one of the PBL compulsory courses was designated an "integrative" course with a role of bringing together students' learning to date, as well as extending their learning.

The four majors are designed to be contemporary and industry relevant, and to further develop students technically and holistically toward the target profile. The majors, each of 8 courses, are:

Application Development and Integration which aims to equip students with additional business and technical skills and knowledge to plan, implement and evaluate large scale systems built from custom-built and packaged software components;

Internet Technologies which emphasises systems development based around the Internet, such as the development of Intranets;

Digital Entertainment which focuses on developing techniques and technologies important in New Media and the leisure use of information technology; and

Electronic Business which broadens students' business knowledge and increases their ability to apply information technology for business benefit.

Because the ICT employment market is accepting of a range of preparations in graduates (as shown by its capacity to absorb those from non-ICT degrees), the choice of major is not a critical aspect of a student's preparation. It follows that the content of a major is not as critical as the content of the compulsory half of the degree.

Because of the desire to reuse existing courses where possible, only the core and any other new courses were planned to be PBL. It was considered essential that students be exposed to the PBL approach from the outset, before they developed the expectation that they would be "fed" information in structured form. PBL courses were to be taught in a 1 hour "plenary session" with a 3 or 4 hour laboratory session, rather than the 2 hour lecture and 2 hour tutorial format generally employed in IT courses at the University.

4 ISSUES FOR STAFF IN DEVELOPING AND IMPLEMENTING PBL COURSES

The academic staff in the School who were to be primarily responsible for developing and teaching the program readily adopted, in-principle, the notion of a problem based degree. Most staff attended the PBL training and development sessions designed to introduce the basics of the instruction method and the development of supporting materials.

In these sessions, as well as in actual implementation, staff experienced difficulty in inverting the traditional way of teaching content-first which has often been reported previously (eg. Gonsalvez & Atchison 2000). They also found it difficult to accept in practice that content might be defined by the problems rather than by their prior understanding of what should be in the curricula. That is, they were challenged by the question: if knowledge is not needed even in the most demanding real world problems, then why should it be in the curricula? It was tempting to formulate unnatural problems that covered the content that would have been taught in conventional degrees. The choice of problems is critical, and the group is still learning how best to do this.

A related temptation was offered because we agreed that PBL is not the most efficient or effective mode for all material. If this is so, then what material is better taught in traditional lecture mode? The novice PBL lecturer is tempted to err on the side of the lecture rather than rely on the problem to help the student discover then absorb the material they need to learn. One way to avoid this temptation appeared to be to let students determine what was covered in formal lectures; as a first semester ploy this did not work as students were undemanding. We are still learning how much direction to give to students, and when..

It is well recognised that it is hard for staff used to traditional delivery mechanisms to learn to focus on process rather than content. To ask students to brainstorm how they will tackle a problem, then provide the right balance of confirmation of ideas or suggested guidelines takes experience. Most staff have also to develop experience in getting students to talk about and evaluate their learning processes – asking students to reflect on their learning process by keeping a diary of a groupbased software development project has been about all that we have in the past done. To devote sessions to discussion of effectiveness as learning tools of the various approaches students have taken is new to us.

Another aspect of design of a PBL course that staff have found difficult is the recommendation not to have a text book, since text books can become a crutch to students in the same way that lecture notes are. Text books are also a crutch to staff entering PBL from conventional teaching modes. The temptation is to think that the "real" content will be covered by the text, even if the students do not pick it up from the problems. The assignment of a text coupled with the use of an exhaustive final examination is insurance for the tentative lecturer, and one that at this stage we are still using for first year.

At the University of Newcastle there are IT courses and/or programs offered by business and by engineering faculties, in addition to the BIT program which is offered by a Faculty of Science and IT. The new BIT draws on some of the courses and teachers from these other faculties. Some of these staff participated in the working group which helped design the degree, as well as in PBL development sessions. Nonetheless, overall there has been an antagonistic attitude to the content of the degree and its use of PBL. The resistance included arguments that the delivery mechanism was too resource intensive, that students preferred structured learning, that structured learning had been proven to be more effective, that there was not room in the 12 compulsory courses for the two design and communication courses, and that mathematics was essential.

5 AN EARLY REPORT ON IMPLEMENTATION

The initial enrolment in the program was 36 students[4], of whom 10 were female[5]. Just under half the intake elected to take the Digital Entertainment major, and 60% of the females did; this major offered one course taught in PBL mode.

Students were exposed to a range of instructional approaches, as in addition to a PBL course, most took the compulsory first year programming taught in conventional mode by the Engineering faculty, as well as the creative design course. The programming course comprised 4 hours of lectures per week in a class of over 200 students mostly studying engineering or IT, as well as a 2 hour laboratory session dedicated to BIT students. The design course was taught with one hour of formal lecture and 3 hours of studio work, in a class dominated by design students but also with some education students. Typical of the three projects in the design course was one which asked students to create a wind mobile which described the design process of something in which they were interested (a hard disc, a highway, a dress, a play or whatever). This description not only had to be in a visual-spatial format to create the wind mobile, but also had to be in written form on a card which hung from the centre of the mobile.

The PBL integrative course in the first semester used three projects. The first of these involved the initial drafting of the requirements for a new web-based version of an existing call-centre based government service. The problem was a current challenge for the organisation and was used as a vehicle for introducing students to the nature of software projects, the development cycle, project management, teamwork skills, and differing development models. In all these topics the ideas were only developed as an introduction to each area but formed the basis for students witnessing the importance of each topic for a successful project. The four weeks committed to this project culminated in a visit by the tutorial groups to the call centre to witness its operational practices and to question the technical manager about their needs for the completion of the related assignment task. Having gained an overview of the development process, the second project was launched with the presentation to the students of a system specification document along with a video description of the user's objectives for a building of a web site for distributing streaming video and audio material developed by students in a different discipline. The project required the design and building of a database backend to the web pages that could track downloads of the individual copyrighted works from the website. Whilst this problem lacked the breadth and complexity of the first problem, it introduced the students to issues of website design and construction, along with database design and construction. The programming skills being developed in

[4] The program was offered at 2 campuses; only the offering at the main campus is described here.
[5] This compared with less than 25% female intake in the University's information systems degree and 10-15% in computer science and less than 5% in software engineering.

concurrent courses provided the ingredients for completing the construction activity. The final project was in the form of a brief from a government agency which described the underlying problem of attracting females into ICT studies. It then asked for a prototype computer game and supporting documentation that would encourage and interest girls in the 11-13 year age group, a target group alien to most of the students. An open source games engine was mandated, and some help with locating information about girls-and-games was provided. The project brought students back to rich pictures and UML, and asked for comparisons of the games scripting language with Java which was the language taught in the introductory programming course.

PBL delivery, at least to a small intake such as this, does not appear to be overly resource intensive, since there is a lower workload in the laboratory sessions than would be the case in a conventional lecture-tutorial mode.

Two thirds through the first semester, a facilitator conducted a workshop for staff teaching current and planned BIT core courses, and conducted two focus groups for students, in which most participated. Staff identified as issues many of the areas of concern that were raised in the focus groups. Of these, the main concerns were the breadth of exposure, including the role of creative design in the program. Some students questioned the breadth of issues generated by the problems and felt that they were getting a superficial coverage rather than in depth learning. Being presented with the problem first made some feel there was prior knowledge expected for the course. Many of the male students found the design course irrelevant, whereas all of the females found it at worst "easy", and most found it a positive learning experience. Because of some complaints received individually from students about malfunctioning groups in which those who knew already "did it all" at the expense of the learning of the other group members, staff rated group work as a problem area more highly than the focus groups did. This may have been because of peer pressure in the focus groups.

At the end of the first semester, the program was reviewed for professional accreditation by the Australian Computer Society. The accrediting panel commended the University for "its support for this innovative program" (Report of ACS Accreditation Panel Visit to Newcastle June 4 2003), and linked accreditation to the continuing application of PBL principles.

6 CONCLUSION

This paper has argued that the ICT educational programs at Universities are conservative, and have not moved to meet the professional environment of the 21st century. The paper described the initial stages of a new Bachelor of Information Technology which has a number of novel characteristics introduced to better match professional requirements. Specifically, the degree explicitly develops students' cognitive and perceptual skills along with their capacity for self directed learning. It encourages creative and risk taking behaviours. At the same time, it seeks to provide graduates with the technical capability of those from a good computer science program, and with the organisational understanding of graduates from a good information systems program. To do all of this in three years, a problem based learning approach has been adopted. The use of PBL, together with other characteristics of the degree, is also designed to make the program more attractive to females.

The development of the PBL materials and of staff capability to facilitate PBL courses is ongoing. As many others before us have found, there is a lot of learning that staff have to do to deliver courses in this alternative educational paradigm. Over the last fifteen years there have been previous attempts to introduce PBL into ICT courses or programs, yet the methodology has not gained a hold in part because of staff resistance. So maintaining enthusiasm is a key requirement for the project.

It is recognised that the PBL mode will not suit all students, as some people learn better in more structured environments. Because of the range of options available to students, including traditional IT programs offered by the University of Newcastle, it is expected that students who do learn effectively with PBL will self select into the BIT. It is also expected that these students will be more employable, and will be more likely to be the employers, in the future.

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