Competency Based Technology Education – a practical approach

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Abstract

There are ever increasing demands to provide computer and network technology curriculum directly relevant to the needs of employers. The failure of institutions to provide students with readily employable skills has been well documented and the debate continues. Typically a newly recruited graduate will be required, by employers to attend various training courses. In response to these demands new curriculum was designed and introduced at Edith Cowan University to incorporate internationally recognized, industry based certification as part of standard undergraduate education. This new curriculum provides the opportunity for students to obtain A+ Certification in computer support and Novell Certified Network Engineer (CNE) standing. This approach of incorporating commercially based education, as part of the curriculum, is now progressively being introduced by other universities within Australia. Experience to date indicates some success but significant inadequacies in standard student evaluation procedures were detected. The authors designed a new competency based approach to student evaluation that: can generate meaningful results to students, lecturers and potential employers; can be conducted as part of a standard workshop with no disruption to normal student activity and provides an assurance of a minimum level of acceptable skill. This paper presents the details of designing, implementing and evaluating competency based evaluation within computer and network technology courses, furthermore the authors make recommendations for the introduction of this type of evaluation to be an essential part of all undergraduate curriculum.

1. Introduction

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 statewide 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' [1].

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. It should be noted that all the students interviewed had successfully completed the standard engineering units of 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.

Preliminary investigations indicated a similar situation with computer science graduates from other universities within Western Australia. The lack of student knowledge of the requirements of industry have been noted by been noted by Havard et al: "On completion of their academic programme the graduate was given no way of knowing how their skills compared to the requirements of industry" [2]. What should be the factors that drive curriculum content other than employer expectations? One view is clearly stated in the 1991 ACM/IEEE-CS report: "The outcome expected for students should drive the curriculum planning" [3]. In this context 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" [4].

The initial ECU student questionnaire, first used in 1993, was also conducted in 1999 at two universities within the UK. A similar study is currently being undertaken in Sweden. One university has well-established degree programs and is fully British Computer Society (BCS) accredited. The other 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. Even though the assignments are intended to simulate work-place activities, there is little or no competency-based teaching or evaluation.

Indications are that, within the UK University sector, practically based curricula with competency testing are not standard practice in computer science. More detailed investigations are currently being undertaken.

2. Curriculum Design

The response at ECU was to design, implement and evaluate a new curriculum in computer and network technology to meet this market need. Four new units were designed – Computer Installation & Maintenance (CIM), Network Installation & Maintenance (NIM), Computer Systems Design (CSD) and Network Design & Management (NDM). A new laboratory dedicated to this curriculum was also commissioned. Each workshop consists of a set of tasks for the student to undertake and all students undertake the same set of tasks in a given workshop. Typical workshops in the CIM unit require students to install and test a range of components such as:

- Master-slave hard disk drive;
- Network interface card installation;
- CD-ROM installation;
- Power supply unit testing;
- Adding electronic memory;
- Basic fault finding exercises using PCs.

Theoretical knowledge includes but not restricted to:

- The operation of CD-ROM drives.
- Hard and floppy disk drives,
- The file allocation tables.
- Basic PC architecture etc.
- Monitor operation and standards.
- A comparison of PC buses.
- Network Interface Cards.

Students in the NIM unit have the opportunity to design, install and test a small Local Area Network (LAN). This includes establishing a file server, client, the construction and testing of cabling, and the design and installation of the directory tree. A small LAN comprising of just those machines in the NIM laboratory, whilst completely isolated from the ECU network, is also used by the students as part of their workshop exercises.

The theoretical work includes, but not limited to:

- Internet and Intranet systems.
- Network media.
- Routers, Brouters, Gateways.
- Packet switching.
- Client server systems.

Lachowicz provides a detailed description of the initial development of the NIM unit [5].

The students work in an environment that simulates, as close as possible, a commercial environment. One part time student, working in the field of computer and network support wrote:

> "I am often asked by staff at work what I'm actually doing at Uni, and how it correlates to work which I do there (network engineering and PC support), however really there is little in common. The material faced during CIM was exactly like a real live situation (which I guess was the desired aim) and this was extremely beneficial. For those who completed the assignments, well, for them it means they have a good leverage of finding work in this field without too much difficulty" .

The results clearly demonstrate that this curriculum is always oversubscribed, attracts students from other universities, has a low student attrition rate, and a very high student satisfaction. According to Maj:

> "The student demand has consistently exceeded possible place. 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%. An independent unit review of the 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" [6] .

The curriculum implemented at ECU is designed to integrate practical exercises (Procedural knowledge) with a theoretical understanding (Declarative knowledge) gained through lectures. The practical exercises are based on industry expectations as determined by the aforementioned survey. According to Cervero "Declarative knowledge is knowledge that something is the case; procedural knowledge is knowledge how to do something".[7] and that: "Both declarative and procedural knowledge are essential for professional practice" [7] However, even though students are taught both procedural and conceptual knowledge only conceptual knowledge is assessed by means of traditional assignments and examinations. None of these assessment methods provides any measure of how well students perform in a workshop environment that is designed to simulate working practices. According to Havard:

> "The world of work requires people who 'know how and not just know what'. Graduates invariably fall into an 'information

gap' of having knowledge about a specific subject area but do not necessarily know how to operate in the working environment" [2].

Furthermore, from a practical perspective there must be mechanisms to help minimize damage to equipment. Maj has 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". [1]

He goes on to say 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" [1].

It is necessary to be able to measure competency thereby providing essential feedback to students and information to prospective employers.

3. Competency

Havard, Hughes and Clarke have noted the general lack of information given to students regarding employer expectations,

> "On completion of their academic programme the graduate was given no way of knowing how their skills compared to the requirements of industry" [2]

Competency Based Assessment (CBA) offers a possible method of testing specific practical skills. Within the new curriculum offered at ECU students are currently assessed by means of a standard written examination and two written assignments. It is possible however, for a student to successfully pass these units without ever attending any workshop. However both declarative and procedural knowledge must be assessed.

Different forms of assessments have both advantages and disadvantages. Written examinations can enable students to demonstrate a greater depth of knowledge while at the same time they may also test a limited breadth of their understanding. Whilst written assignments can give students an opportunity to search literature and show understanding, multi-choice questions provide the means to test students with minimum effort across a large portion of the syllabus, but may not allow students to show their in depth knowledge. However, CBAs may be used to test practical skills not tested via other forms of assessment. It can be concluded that no single assessment technique is sufficient if both procedural and conceptual knowledge are to be assessed.

The relevance of CBA in the university sector is questioned by Hamly cited by Wilson:

> "Frank Hamly, the executive director of the Australian Vice-Chancellor's Committee, said in a graduation address, that he believed that most of the higher order intellectual skills which universities impart are not capable of measurement as competencies and that universities must therefore resist their implementation" [8].

However according to Veal:

> "Merely because the higher order skills may not be capable of measurement this should not of necessity exclude measuring other very important and potentially commercially relevant skills." [8].

Accordingly the authors designed and tested CBAs for two units in the new curriculum - CIM and NIM. The workshops are typically implementations of the preceding lecture. All workshop details are provided including objectives of exercise, learning outcomes, equipment checklists and details of each experiment. At the start of each workshop the tutor provides a demonstration of the experimental procedures. The required outcomes from the workshop tasks were grouped under appropriate headings, thereby defining a set of competencies.

The defined set of competencies for the CIM unit were:

A. Testing and checking
B. Safe work practices and protection of equipment.
C. Manipulative awareness and skills
D. Interpretation of instructions. Knowledge of systems
E. Fault diagnosis and correction.

To ensure that the CBA was easy to use the authors elected to use simple binary evaluation criteria i.e. pass or fail. By example for the unit CIM the check points used for set B of competencies were:

B Safe work practice and protection of equipment.

[ ] 1 Mark Disconnects from mains when appropriate.
[ ] 1 Mark Takes power lead out of back of system box.
[ ] 1 Mark Uses Anti-static strap at appropriate times.
[ ] 1 Mark Places equipment in such a way as not to cause potential problems.
[ ] 1 Mark Re-assembles computer correctly.
[ ] 1 Mark Polarity of all cables correct.
[ ] B Subtotal of marks

For the unit NIM a different set of competencies were defined as:

A Creation and Deletion of Objects
B. Assignments and Settings
C Accessing the Network

For the unit NIM we chose the experiment of creating a ‘Black Hole’ using the Novell Network Operating System. The checkpoints used for set B of competencies were:

B. Assignments and Settings

[ ] 1 Mark Makes user trustee of Black Hole OU.
[ ] 1 Mark Gives user supervisory object rights.
[ ] 1 Mark Determines IRF to apply
[ ] 1 Mark Correctly applies the IRF
[ ] B Subtotal

The assessor moved around the workshop checking off the sheet for each student being evaluated. Each student had a separate sheet with a standard clear and simple layout for ease of marking.

4. Results

It was found that the CBA used was easy to manage as part of a normal workshop. No extra time was taken during the standard two-hour workshop period yet it was possible to assess all twenty students in each workshop. According to Veal for the CIM unit**:**

> “The students were assessed during a standard two-hour workshop. The work was conducted in a normal manner with the assessor independently evaluating students. At no point was the workshop interrupted, or extra time taken. Ten students were evaluated. Despite the fact that considerable emphasis is placed on ensuring that students are provided with the highest possible standard of good workshop practices to underpin Health & Safety the results clearly indicated that some students did not demonstrate a satisfactory competency in basic safety practices. It would not have been possible to determine this result without a CBA” [8].

For the NIM unit the results showed that most of the students could sucessfully complete the tasks. However, one student was unable to create a black hole; another could not apply and inheritence rights filter correctly and a third did not manage to delete all of the objects that they had created. Further work is currently being undertaken to evaluate consistency between evaluators and the effectiveness of CBA as feedback to students. Furthermore the authors are investiging the value of CBA as an evaluation tool for the benefit of prospective employers.

5. Engineering Education - implications

The unit CIM was independently evaluated by an educational expert in order to assess students’ perceptions of the unit CIM, the educational approach taken and the educational value of this unit [8]. 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. 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. 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”. Students appreciated the modular organization of the unit. One student thought that “the practical side was really good and I learnt a lot”. Significantly a fourth year engineering student was also interviewed. He 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 visualize what they are working with”. This student was not an exception.

Typically about half of the students enrolled on the unit CIM are computer science majors. However, most semesters engineering students also enroll on this unit. Certainly questions must be asked why final year B.Eng students should attend a first year units, with no pre-requisites, in computer and network technology. The B.Eng degree at ECU has three streams: Computer Systems, Electronics and Communications. Six B.Eng students, who attended the CIM unit, were interviewed. Further work needs to be done but the results to date suggest that the B.Eng curriculum fails to provide sufficient workshops to reinforce the conceptual content of the curriculum. Furthermore, the students interviewed had little knowledge or experience of standard workshop practices such as the use of anti-static straps, residual current detectors etc.

6. Conclusions

The new demand driven curriculum in computer and network technology at ECU requires students to work on equipment in a manner that simulates a typical commercial environment. The workshop environments for some units are potentially hazardous to students. This mandates that students be assessed for their competency. However traditional assessment methods do not assess competency. Accordingly a simple CBA was designed and tested. The CBAs used in this study were found to be simple to design and used. Furthermore they could be used as part of a normal workshop with minimum interruption to normal student activity. Significantly, despite the fact that considerable emphasis is placed on workshop practices to underpin Safety & Health requirements the results from the CBAs clearly indicated that some students failed to achieve an acceptable level of competence. It would not have been possible to determine this without CBA. Indications are that CBAs could be applied to other computer science units. The authors are currently conducting further tests of CBAs on a larger number of students and a range of different units. There are implications for the B.Eng award at ECU. Preliminary results indicated that such students are not provided with sufficient or appropriate workshops to reinforce the conceptual content of the curriculum.

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