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Realising core graduate attributes in Computer Science through a CPR (Collaboration-Participation-Relevance) approach to teaching

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Abstract: *This paper describes an approach to teaching developed in response to the introduction of the Core Graduate Attributes (CGA) Policy at Victoria University. The policy recommends that, upon graduation, students be equipped with a variety of skills including the ability to solve problems, communicate well, work autonomously and collaboratively, and to perform effectively in diverse settings. The CPR approach aims to realise these policy objectives by emphasising collaboration, participation and relevance in teaching and learning. This paper reports on the application of the CPR approach to three subjects of an undergraduate Computer Science course. In the first year programming subject, the focus was on honing initiative and collaborative skills. To this end, group assignments and open-ended scaffolded assignments were introduced as part of the assessment. The assignments were divided into two parts; part one required a standard solution, and was to be attempted by all students; part two recommended, and called for, possible extensions, allowing students to use their initiative and gain additional marks. The CGAs addressed in the second year Intelligent Systems subject included evaluation and effective management of information, as well as communication and presentation skills. Here, student 'experts' assumed the roles of lecturers, presenters and demonstrators; they showcased their research, demonstrated applications of commercial software, and presented solutions to pertinent artificial intelligence problems. In the final year Project subject, involving the design and implementation of a real-life computer application for an external client, the emphasis was on problem solving skills, communication skills, leadership qualities, and personal presentation.*

Keywords: *Learning; graduate attribute; computer science.*

Introduction

The development of the Core Graduate Attributes Policy at Victoria University has been a response to concerns about improving the employment outcomes of new graduates, and has focused on employer satisfaction with graduate skills (AC Nielsen, 2000; Sinclair & Doughney, 2001). The selected CGAs include problem solving, using information, communication, working as a professional, and appreciating diversity; they were designed to produce graduates with a capacity to lifelong learning. They relate strongly to the development of empowered and critical members of society as well as to the enhancement of employment outcomes. Each of these attributes is perceived further at three levels, which fit the three-year pattern of a standard arts/science degree. It is intended that students should develop these attributes whilst studying their course and, upon its completion, should have attained a level within each attribute that is consistent with entry to the professional workforce. The University has adopted an in-context curriculum integration model for the development of the CGAs. As curriculum is conceptualised over the student's whole course, ideally, each attribute should be revisited and assessed both in various subjects, and year by year at progressively higher levels. And, as for most students assessment drives learning, the focus should be on assessment tasks (McDowell, 1995).

Implementation of the policy poses a number of challenges at both the macro and micro levels. At the macro level, it has to be decided to what extent individual subjects within the course support the development of the CGAs in students; all subjects making up a year have to be examined to see if any of the CGAs have been neglected and, if necessary, suitable adjustments have to be made to subjects to meet the requirements. At the micro level, innovative teaching and learning approaches, which aim at maximising the development of the CGAs in students, need to be determined. This paper presents one such approach. The approach, based on three fundamental principles of collaboration, participation, and relevance, aims at engendering CGAs through optimising students' ability to benefit from teaching. It concentrates on learning and teaching situations while maintaining focus on the quality of learning. The paper identifies the principles underpinning the approach; it refers the approach to related research findings and it reflects on the application of the approach to three subjects of a Computer Science course.

The CGA policy

The development of the CGA policy at Victoria University was based on the examination of evidence regarding employer requirements and extensive consultations with University staff. The details of the policy, i.e. a set of core graduate attributes were developed according to the framework provided by Boyer (1990). Boyer defined four complementary aspects of scholarly work: scholarships of discovery (conducting research), integration (making connections within disciplines and across disciplines), application (focusing on professional practice and real-world problems), and teaching (transmission, transformation and extension of knowledge). According to Candy (2000), these areas of scholarship are also useful for conceptualising the activities of knowledge workers outside of university. Consequently, the four areas of scholarship coupled with information from employers were used to define the core graduate attributes. These attributes represent generic skills that all students, regardless of area of study, should possess at graduation in addition to the specific knowledge and skills of their discipline. However, it was recognised, even by Boyer, that the scholarships were interrelated and it was therefore not possible to match each attribute to a single area of scholarship. Nonetheless, it was believed that the four scholarships would provide a useful conceptual framework for the CGA policy. According to the policy, a Victoria University graduate:

1. is an effective problem solver in a range of settings, including professional practice;
2. can locate, evaluate, manage and use information effectively;
3. communicates effectively as a professional and as a citizen;
4. can work both autonomously and collaboratively as a professional;
5. can work effectively in settings of social and cultural diversity.

Each of the above attributes is to be developed at each year level of a course, and relevant criteria for each level have been defined. Since most university undergraduate courses are of three-year duration, a three-level model applies. The students' graduate skills are to be developed progressively over time. Thus they should begin with less demanding and more familiar tasks in the first year of their studies and, in second and third year, proceed with more complex tasks further removed from their original experiences. This process should facilitate students' transition from novice undergraduates to professionals. Although the core graduate attributes have been defined as generic, they are context dependent. Consequently, their integration into the curriculum will vary between disciplines and courses. In fact, the development of graduate skills has been incorporated in most courses across the University for years, albeit in an implicit manner. The CGA policy aims to make this development mandatory, uniform, systemic and explicit. To this end, the implementation process involves course curriculum mapping against the CGAs at course level, and coordination of the overall implementation at faculty level.

Curriculum mapping involves a number of steps to be performed by a course team including a course coordinator, year level coordinators and subject coordinators; firstly, the existing curriculum of each subject needs to be examined to identify learning and assessment activities that support the development of each CGA; secondly, the extent of this support has to be established; thirdly, any gaps and inconsistencies need to be identified and remedied. Curriculum mapping should be applied to as many subjects as possible in a given course but, where the course structure allows a great number of elective subjects, it may be necessary to confine the mapping to core subjects of the course only.

Naturally, the introduction of the CGA policy has also affected the curriculum design and assessment practices of the undergraduate Computer Science course. The response to this policy has been twofold, at the macro level, the required curriculum mapping process is to be followed; and at the micro level, innovative teaching and learning approaches have to be determined. While the activities at the macro level have only just begun, at the micro level a CPR approach to teaching has been developed and recently "road tested" in three different subjects of the course.

The CPR approach

The development of a teaching approach that would reflect the CGA framework was not just about the activities of the teacher; rather it was a plan for students' learning. The plan had to include the presentations that the teacher would make, the exercises and activities in which the students would participate, materials that would be supplied to the students, and ways in which students' understanding and capabilities would be assessed. The approach was based on several conceptual frameworks for learning and teaching, all of which advocate CPR – collaboration, participation, and relevance – in learning and teaching.

Firstly, to produce graduates who are "effective problem solvers in a range of settings", the approach promotes Problem Based Learning (PBL) throughout the entire course. Many variations of PBL have been documented, but all of them include situations where an initial problem serves as a catalyst for subsequent learning (Fogarty, 1997; Kingsland, 1996). The learning that occurs in working with the problem enables students to develop new knowledge, as well as further consolidate their existing skills and knowledge (Schiller, Ostwald & Chen, 1994). Students participate more in their own learning and receive less guidance from the teacher – factors distinguishing PBL from subject-based learning (Dolmans, 1992). The role of the teacher is different too: it is one of consultant rather than instructor. PBL usually includes a collaborative component; students often work in groups where collective decisions are made about task distribution, and where group members investigate different aspects of the problem that together contribute to the total solution. This collaborative component of PBL has been given particular importance in the CPR approach.

Secondly, in addition to PBL in a collaborative environment, the CPR approach advocates the pursuit of worthwhile projects and, particularly in the final year of the course, real projects commissioned by real clients. The emphasis on "authentic" tasks, PBL, and collaboration exemplify the three components of another framework for learning – Engagement Theory. The major premise of engagement theory is that students must be engaged in their course work in order for effective learning to occur. The theory posits three primary means to accomplish engagement: (1) an emphasis on collaborative efforts, (2) project-based assignments, and (3) non-academic focus. It is suggested that these three methods result in learning that is creative, meaningful, and authentic (Kearsley & Schneiderman, 1999). Engagement theory is based on the idea of creating successful collaborative teams that work on tasks that are meaningful to someone outside of the classroom. Its core principles are summarized as "Relate", which emphasises characteristics such as communication and social skills that are involved in team effort; "Create", which regards learning as a creative, purposeful activity; and "Donate", which encourages learners to position their learning in terms of wider community involvement.

Thirdly, the approach encouraged integration of theory with meaningful practice. According to Brown, Collins, and DuGuid (1989), context and situation are essential to all learning, so students need to engage in real activities that have purpose and meaning. This facet is also associated with the experiential way of learning, described by Kolb (1984), and Kolb and Fry (1975) as a cyclical process passing through four stages: experiencing, reflecting, concluding and testing. The experiential method was specifically developed to link theory to practice in a way that would promote "deep" rather than "surface" learning. It was agreed that in the approach, introduction of theoretical concepts would be supported either by relevant practical laboratory tasks, or presentations of real-life applications.

Fourthly, CPR has adopted scaffolding as a way of encouraging students to conduct research and fashion new insights. Scaffolding is an inquiry-oriented teaching strategy, based on engaging tasks, that aims at transforming students into independent and self-regulating learners and problem solvers (Hartman, 2002; McKenzie, 1999). During a scaffolded task, an expert – usually the teacher – provides students with advice and examples, guides them in practice, and then tapers off support until students can do the task alone. Such structuring encourages students to develop their own initiative, motivation and resourcefulness – qualities synonymous with the CGAs. The CPR approach encouraged students to assume the role of experts/teachers, whenever appropriate. Research promotes reciprocal roles of teachers and learners, and stresses their interdependence (McLoughlin & Oliver, 1999). It also advocates a shared responsibility for creating and exploring knowledge (Scardamalia & Bereiter, 1991, 1994).

Finally, the CPR approach placed particular emphasis on final and all-encompassing subjects in the degree program. In these subjects students synthesise and consolidate knowledge acquired throughout their studies. Fairchild and Taylor (2000) define such experiences as capstones. In addition to integration, experiential learning, and real-world problem solving, capstones emphasise teamwork, decision-making, critical thinking, and interpersonal communication. These are non-technical skills considered essential in many types of work, and computing work is no exception; graduates are expected to demonstrate technical skills, as well as project management skills, and awareness of business practices (Fairchild & Taylor, 2000; Magney, 1996; Novitzki, 1998).

Implementation

First year - Programming

Java Programming is a mandatory first year programming subject. In this subject, the CPR approach addressed particularly the development of the following CGAs at basic level: collaborative skills, problem solving skills, and initiative. Group assignments and open-ended scaffolding assignments were introduced as a means of developing the skills in students. For instance, in one of the assignments students were required to write a program to play a game. The assignment was divided into two parts; part one called for a typical solution to the problem, and was to be attempted by all students; part two recommended possible extensions, as illustrated in Figure 1, and allowed the more motivated students to enhance their game programs and gain additional marks.

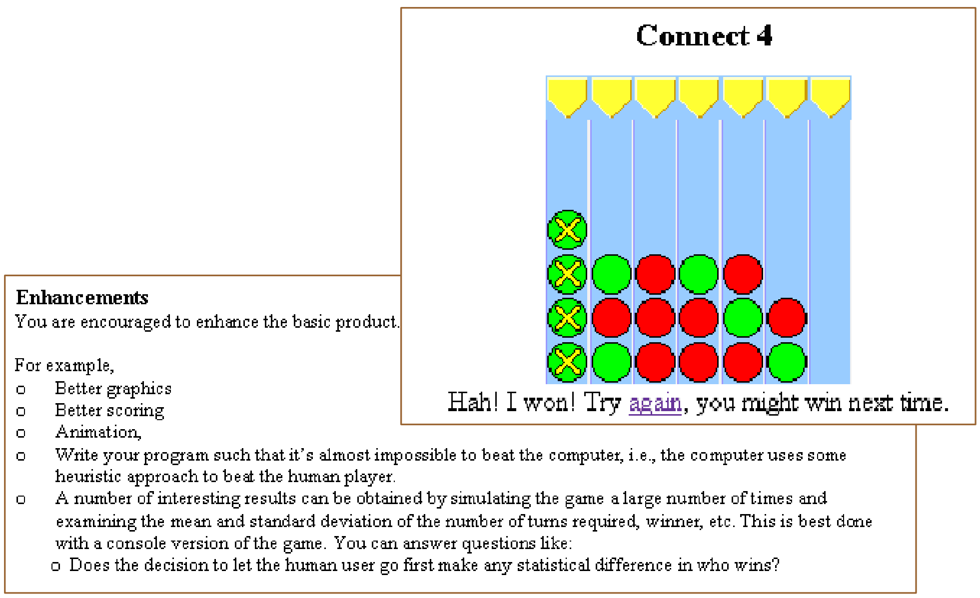

Figure 1: Scaffolding assignment

This first year programming subject is considered crucial, as it often shapes students' perceptions about the entire course and, if taught well, it helps sustain students' interest, and ensure their success in the course. To boost students' confidence in their programming skills, an on-line assignment submission system was developed. The system enables students to test their programming assignments extensively while providing instant automatic feedback to each submission. The system serves as a "supplementary" automatic tutor and gives the students an additional opportunity to perfect their programming skills.

Second year – Intelligent systems

Intelligent Systems is a second year subject that covers a diverse selection of topics in the field of artificial intelligence. The intermediate level CGAs targeted in this subject included location, evaluation and effective management of information, communication and presentation skills, as well as problem solving. In this instance, student "experts" were called upon to assume the roles of lecturers, presenters and demonstrators; students showcased their research, demonstrated applications of commercial software, and presented solutions to pertinent artificial intelligence problems.

On one occasion, a student who participated in the 2002 Robocup tournament – an international competition for students competing in a game of robot soccer with their custom designed and built robots – gave a presentation to the Intelligent Systems class. Armed with two competitive robots, depicted in Figure 2, and video footage of the various stages of the competition, the guest lecturer related some of the difficulties associated with mounting a successful Robocup challenge, and demonstrated solutions to the generic problems of computer motion, vision, and interactive co-operation between computers. The demonstration was interwoven with hands-on trials and punctuated by anecdotes. It stimulated interest and discussion on the Robocup competition, robots and intelligent systems.

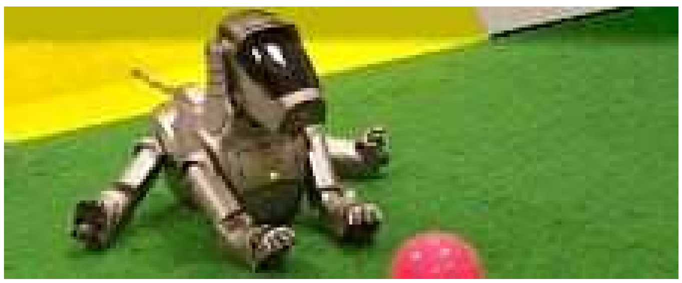

Figure 2: Robocup demonstration

On another occasion, "expert" students designed and conducted interactive demonstrations on neural networks for their fellow students. Four different problems were chosen, and solutions presented, using a commercial neural network software package. In one case, the application of a neural network was a deliberate counter-example, as the neural network did not provide a suitable solution and its use was not appropriate. The other three cases were classical problems that could be solved using a neural network. All four demonstrations stimulated experimentation and discussion that reinforced learned theory presented in lectures. An assessment exercise was then set that required participating students to submit a written report answering several key questions about the four given problems. These questions solicited students for comments on what they had learned from the peer-led demonstrations.

In addition to presentations and demonstrations, practical sessions were structured in a way that gave students the opportunity to experience, test and reflect upon practical applications of theory presented in the lectures. For example, after the topic fuzzy logic had been covered in lectures, students simulated the operation of fuzzy logic based systems; one was a shower with fuzzy inputs of hot and cold water and valve pressures; another, a commercial washing machine with fuzzy control of washing cycles.

The development of the targeted CGAs was further re-enforced through continuous assessment, which comprised three parts: a project, a mid-semester test, and a report on a tutorial demonstration. While the mid-semester test examined the understanding of the topics covered in the first part of the subject, and the tutorial report tested students' ability to reflect on the relationship between theory and practice, the project was a creative task. It involved the design and implementation of a rule-based expert system. In a lead up to the project, students were expected to complete a set of standard tutorial exercises to learn the basics of an expert shell known as JESS, and then apply the acquired skills to solve a real-world problem. The project specification detailed grading for a range of solutions. A standard solution, worth 70%

of the total mark, involved the creation of a typical expert system that adequately solved the problem. Several possible extensions to the solution were suggested, and students were encouraged to incorporate these, or other possible extensions, to enhance the functionality of their expert system. Additional marks were awarded for these extensions, their number dependent upon the degree of difficulty and innovation involved.

Third year – Project

The final year Project subject involves the design and implementation of a real-life computer application for an external client. It provides students with an opportunity to manage a project, work in a team, and liaise with clients, thus emulating a real-life information technology environment, which they can experience prior to entering the workforce. Hence the Project places special emphasis on the development of relevant advanced CGAs including problem solving in professional practice, effective communication, leadership, and competent performance in diverse social and cultural settings. While working on the Project, students must undertake a co-requisite subject in English Language and Communication. The English subject focuses on consolidating written and oral communication skills such as compilation of technical reports, and delivery of oral presentations – skills directly relevant to the Project. Thus the Project provides students with an opportunity to develop and improve these essential skills before they enter the workforce and, as such, is likely to influence their future employability.

Project students, under the supervision of a staff member, tackle a software development problem for a company or organisation. Typical projects include design and development of database applications, Web based applications, or software modules for computer packages; integration and enhancement of existing software modules and, system analysis and simulation studies of production and inventory systems. Students are divided into groups of three or four; each group is allocated a project, a sponsor – the client, and an academic supervisor. Each group works on the allocated project whilst liaising with the client and consulting with the supervisor, submits reports, and gives presentations. Their work is further helped and scrutinised by the English lecturers who, while not familiar with the computing side of the projects, are language and communication experts. They play a vital role in helping the often reluctant computing students appreciate the importance of good communication skills: the effect of an articulate interview, the impact of well structured and clear reports, and the power of well prepared presentations.

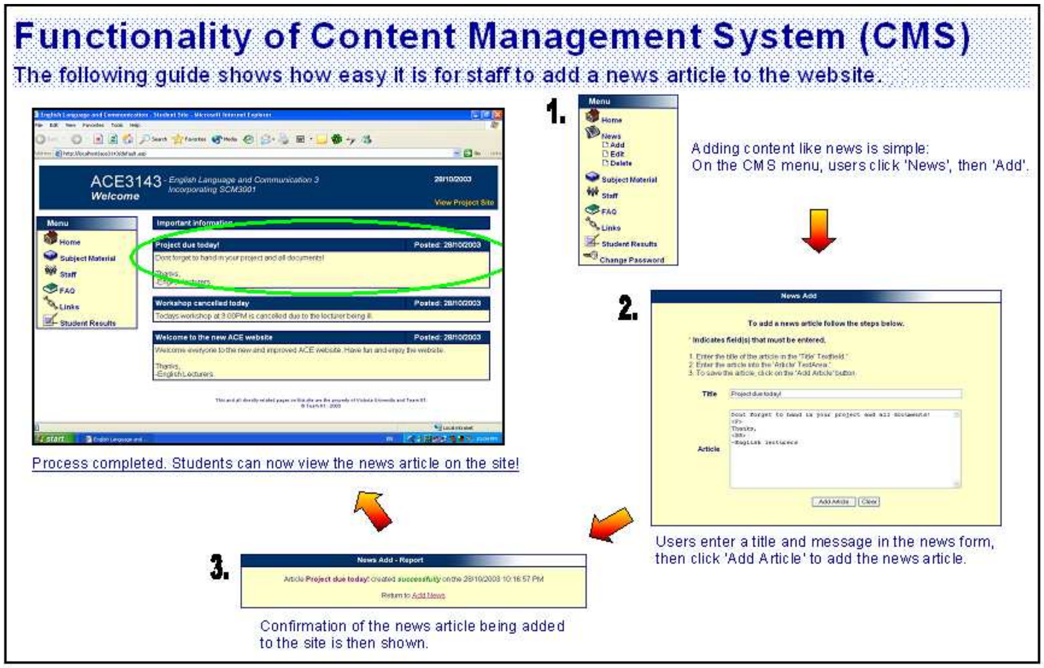

Figure 3: Content Management System

One of the most recent projects took the development of CGAs to new heights, in that a group of students developed a Web-based Content Management System, depicted in Figure 3, for "special" clients – their English lecturers. This unique scenario created two levels of learner/teacher engagement whereby each of the parties involved played the role of learners on one level, and the role of teacher on the other. On the English language and communication level, the English lecturers played the role of teachers, and the students were the learners. However, on the computing level the roles were reversed, the students provided service, and the English lecturers learned. The reciprocity of roles created an implicit understanding that teaching and learning was a shared responsibility; teachers were open to learning and, students were capable of making a relevant professional contribution.

Conclusions

The demand for "well-rounded" university graduates is growing as employers increasingly seek degree holders who, apart from their professional qualifications, can also demonstrate a variety of generic skills considered essential in a real-life working environment. The development of such skills in students is a challenging task, and appropriate mechanisms have to be put in place to meet the challenge. While addressing the issue at an institutional level is a necessary step, and the introduction of a relevant policy will result in curriculum changes, the success of the policy will depend on effective delivery of the amended curriculum. One possible delivery method, a teaching approach created in response to a policy, has been described in this paper.

The approach particularly promoted three aspects of teaching and learning: collaboration, participation and relevance – CPR. These three aspects directly supported the development of the relevant graduate skills in students including the ability to solve problems, communicate well, work autonomously and collaboratively, and to perform well in diverse settings. The initial application of the CPR approach to three different subjects of a Computer Science course confirmed that the approach can support the development of graduate attributes at all course year levels, and indicated strongly that tailored assessment tasks are particularly helpful in developing these attributes.

It is difficult to implement a teaching approach that incorporates problem-based learning within existing traditional subject boundaries. The tensions inherent in this context need to be addressed at the institutional (macro) level. However, the CPR approach is an ongoing research project and a number of issues still need to be further investigated at the micro level, for example, the suitability of the approach in other subjects of the course, ways to improve the rate of participatory teaching, and, most importantly, methods to measure the effectiveness of the approach objectively.

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