Evaluating use of an online concept mapping tool to support collaborative project based learning

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Abstract: The undergraduate engineering program at Central Queensland University (CQU) has been delivered using a collaborative, project based learning approach since 1998. This approach is supported by Engineers Australia to promote development of graduates with strong professional capabilities, and receives strong support from students, graduates and industry. This on-campus educational approach is now being developed for distance education in engineering and building, requiring an online learning environment that supports teamwork, problem solving and project based learning. A number of online tools are being developed to achieve this. This paper outlines the current status of developments in the use of one online tool, Cmaps, a concept mapping tool intended to facilitate early stages of collaborative online project work. Cmaps is a web-based, platform-independent and open source visual and collaborative tool that is intended to supplement use of text-based email and discussion forums during problem solving and early stages of project development.

Emergence of online collaborative project-based learning at CQU

Studies into the education of professionals in many fields including medicine and engineering support use of social constructivist learning environments. Such environments facilitate balanced and integrated, development of technical capabilities on the one hand, and social and personal professional capabilities on the other. Technical capabilities cover just two of the ten professional graduate attributes specified by Engineers Australia (2005) guidelines for program accreditation identify.

Traditional approaches to engineering and building education focus on technical knowledge and fail to give sufficient attention to explicit, structured development of other essential professional capabilities. This leads to what Engestrom (1991) has called 'encapsulation' of technical knowledge, a process that prepares students to demonstrate that knowledge in academic settings, but leaves them less capable of applying that knowledge in the real world. Encapsulation of technical knowledge is a particular problem for less academically inclined students (Biggs, 1999), and is best avoided by engaging students in active learning approaches that are inherent in problem and project based learning. A number of studies call for increased use of problem and project based approaches to learning (Thomas, 2000; Major & Palmer, 2001; Felder & Brent, 2004). Professional capabilities are further enhanced by systematically engaging students in collaborative learning (Johnson, Johnson & Smith, 1998; Johnson & Johnson, 1998; Felder & Brent, 2001) to develop skills required to operate effectively as professionals in teams in the engineering and building industries.

The Bachelor of Engineering program at Central Queensland University was developed and offered in 1998 following the approaches outlined above to provide a collaborative, problem and project based learning environment that prepared students for graduate employment as professional engineers (Jorgensen & Senini, 2006). It is an approach that is consistent with the requirements for professional accreditation:

> Engineering application activities should be pervasive to the curriculum and include complex problem solving, design and project work… Students should engage with complex, open-ended problems and work in both individual and team capacities. The curriculum should contain multiple design tasks, research and project activities spread throughout the various levels. Engineering application work should … fully embrace broad contextual considerations … to develop an appreciation of the interactions between technical systems and the social, ethical, legal, political, environmental and economic context in which they operate. (Engineers Australia, 2005, p.13)

This program-wide, collaborative, project-based approach outlined above has been used for almost ten years in the Bachelor of Engineering (BEng) degree offered to on-campus students. It has been very successful and is strongly supported by both students and employers. Graduate Destination Surveys shows that the salaries and the employment rates of CQU BEng graduates are consistently above the Australian averages.

During this period, Central Queensland University (CQU) also offered a Bachelor of Engineering Technology (BEngTech) program in which most students studied in a traditional print-based distance education mode. A collaborative PBL approach to program design was not considered when this program was initially developed because information and communication technologies were not adequately developed or accessible to students. In recent years this program has become more interactive with use of email and some development of online teaching using Blackboard.

Accreditation feedback in 2002 invited the Faculty to consider expansion of its PBL approach to all undergraduate engineering programs. The subsequent review of these programs identified a need to align the BEngTech program more closely with the BEng program, and to offer the BEng program in both on-campus and distance education modes. In 2006, the Program Review Committee considered the merits of these initiatives and the technologies available to support online learning, and determined that the distance education programs should provide students with an online learning environment that supported active, collaborative, contextual and project-based learning. Distance education students were to be provided with a learning environment that would support development of learning outcomes and targeted graduate attributes equivalent to those specified for the on-campus BEng and BEngTech programs of study. The Committee specified that a requirement for enrolment in all courses in these programs was that students obtain frequent, regular access to the Internet.

The curriculum design challenge was to develop a distance education program that provided a collaborative, PBL learning environment. The design drew on and brought together experience gained in ten years of offering the BEngTech program in a traditional, largely print-based distance education mode, and on experience gained in delivering the BEng on-campus using a collaborative, problem and project based learning approach.

A number of online tools are being developed and tested to support these learning activities. The Blackboard application provides the basic online learning environment through which all learners access their courses, are guided through their studies and communicate with each other, with tutors and within project groups. To support project research activities, learners can use the CQU Library to access journals, books and references like standards; or they can search the Internet. To support student access to industry design, modelling and analysis tools, CQU is developing systems to provide remote access to software or to issue required software to students by sending them secure, dedicated external drives with the software. Documentation and presentation activities require students to use standard office software.

Extensive research into cooperative learning by Johnson & Johnson (1998) clearly indicates that the success of learning teams depends on explicit teaching to develop required team skills and establishment of a culture of teamwork in the learning environment. Thus Distance education students

are advised to begin studies by taking Engineering Skills 1, a course specifically designed to develop the skills required to study online successfully as a member of a project based learning team. Distance education students undertake the same collaborative projects and complete the same assessment as on-campus students whose team building induction program in Week 1 is joined with the distance education students' Week 1 Residential School.

In 2007, the first year of the revised program, 136 students completed Engineering Skills 1, including 34 distance education students who studied online. In the first week of the course, all distance education students attend a Residential School in Rockhampton, to meet fellow students, develop collaborative learning skills and begin to use online tools. These students studied the remainder of their course in the distance education mode and completed a number of collaborative projects using Blackboard, email, telephones and informal face-to-face meetings where group members live near each other. Student feedback about the course was very positive and 91% of students completing the online course obtained a pass grade or better. This compared well with the 92% successful completion rate for the on-campus cohort in Term 1, 2007 and with the 89% average completion rate for Engineering Skills 1in the four years to 2006. The effectiveness of the teamwork in the distance education mode is illustrated by the actions of two students who wished to (and were free to) withdraw from the course, but decided to continue to support their team to complete team projects.

While further research is necessary to confirm that a collaborative PBL learning environment can be replicated online for distance education students, the results indicated above suggest that there are no major obstacles. However, the program technology strategy seeks to provide distance education students with a learning environment that parallels both the on-campus environment and the environment of professional practice. Observation of project teams in on-campus courses indicates that such students commonly use diagrams and engage in activities like brainstorming, mind-mapping and concept mapping when teams explore and shared ideas, develop projects and addressed problems. A concern that emerged in developing the online educational technology strategy to support collaborative PBL was that the group communication support tools such as those available in Blackboard are largely text based and may limit effective group functioning in some phases of project development and problem solving.

Visual and text based collaboration tools

In the classroom and in the engineering workplace, much collaborative project concept development and problem-solving involves sketching and diagramming rather than use of text. Berners-Lee explained the process he encountered in trying to facilitate communication and problem solving between engineers, scientists and programmers at CERN (the European particle physics laboratory: Geneva) "Informal discussions at CERN would invariably be accompanied by diagrams of circles and arrows scribbled on napkins and envelopes because it was a natural way to show relations between people and equipment" (in Berners-Lee & Fischetti , 1999, p.11). Berners-Lee went on to develop the World Wide Web in an attempt to address this project development and communication problem. Unfortunately the WWW currently supports mainly text-based communication systems. Harasim et al (1995) point out that;

> Learning networks … have been generally characterised as text based because the majority of network systems are still text based. However there is clearly a need for communication involving graphics material as well. (p. 249)

Hypertext was originally envisaged as a metaphor for the way humans create ideas by forming non-linear networks (webs) linking ideas and concepts.

> The way we think about things is highly non-linear, and that having to linearize our thinking in order to convey it to others limits our creative function. It is also a fundamental limitation on the ability of groups to function as teams exhibiting 'collective intelligence'. (p. 252).

Cognitive tools are digital tools that can help us think, that facilitate cognitive processes, and can stimulate higher level thinking (Gagne et al., 2005). Kahneman and Frederick (2002) identify two basic human thinking systems.

- The reflective thinking system is controlled, effortful, deductive; it involves rule application and slow, serial processing of information, focuses on abstract generalities and is emotionally neutral.
- The intuitive system is uncritical, effortless, associative; it involves skilled action based on experience and rapid, parallel processing of information, focuses on concrete specific experiences and emotional engagement.

Text itself is a serial medium that requires effortful, slow and serial processing of information online collaboration tools based on text provide good support for reflective human thinking. Writing, the production of text is also a slow, serial and rule-based process that abstracts objects and processes in language.

On the other hand, graphics can often be understood at a glance or sketched to show ideas, they use two-dimensional space to show associations, and they are processed as a whole rather than serially, and can provide direct representations of concrete objects.

Additional research into human thinking processes (Dijksterhuis et al, 2006) suggests that in complex situations, intuitive thinking processes are the key to better decision-making following reflective analysis of problems than the application of reflective thinking alone. This has implications for online PBL where students are given complex and ill-founded problems that require reflective analysis and intuitive decision-making. It is important that the cognitive tools made available to students support both reflective thinking (where text-based tools are likely to be most productive) and also support intuitive thinking processes (where visual cognitive tools provide effective support). This understanding led to a search for visual cognitive online tools that would support intuitive thinking processes and complement the traditional text-based online communication processes.

Visual tools to support collaborative online learning

Recent literature about online learning practices provides focuses mainly on the use of text-based tools to support collaborative learning. In their review of online learning technologies, McGreal and Elliot (2004) identify visual technologies like streaming video and web white boarding which are used mainly as didactic presentation media. They mention peer-to-peer file sharing which can be used by project teams to share information, but leads to problems with version control and accessibility of recent active versions of files.

The Blackboard application that is the core application used by CQU to support online learning offers a 'virtual classroom' facility that allows students to interact using graphics tools on screen, and can be used for brainstorming, sharing and mapping concepts, but it is designed to support synchronous interaction that may suit tutorial support, but presents problems for distance education students, particularly in engineering. Many of these students work long shifts and have irregular breaks so synchronous activities can be difficult to arrange and asynchronous visual collaboration tools would allow students to work together more effectively.

A survey of visual cognitive tools identified a number of applications that were considered. The two main types of applications were those that supported concept-mapping, and those that supported mind-mapping. Concept-mapping was initially developed by Novak (1991; 1998) to allow students to demonstrate how they have constructed their understanding of concepts, particularly science concepts. Concept maps show concepts as nodes in a diagram, show relationships between the nodes as arrows that are labelled with propositions explaining the relationship between the nodes (Novak & Canas, 2006). A network of nodes and relationship arrows is constructed to represent visually concepts associated with a question, issue or problem. The combination of more intuitive visual elements and structures, and the requirement to exercise reflective thinking in order to describe relationships that connect concepts requires users to integrate the intuitive and reflective human thinking systems identified in the work of Kahneman and Frederick (2002).

Initially mind-maps (Buzan, 2002) appear to be similar to concept maps but concept maps can be more complex, showing a number of hubs of ideas and more complex webs of links whereas mind maps have one central idea and more linear, hierarchical branching structure that adapt more easily to outlining in word-processing documents. Mind mapping does not require users to explain the relationships between the ideas expressed in the map. Mind-maps address a central issue or question

that is usually shown in the centre of the diagram, and ideas related to the central issue radiate from the centre and ideas are expanded in more and more detail as one moves from the central idea. This arrangement is more intuitive, ideas can be placed on the page as text comments of images using cycles of brainstorming, then ideas can be arranged and linked into the mind map.

Concept-maps and mind-maps can be used by individuals to clarify their own understanding of issues and to identify knowledge gaps that require further learning research. They can he used by teachers to evaluate students concepts, misconceptions and weaknesses in understanding, and can be used by students in the same way to support collaborative learning. They can be used by professionals (and students) to make explicit the knowledge that groups bring to a project and to develop a shared understanding of problems within a team. They can be used to support scoping of problems, planning of projects and reports, and evaluation of individual and team work to identify faults, misunderstandings and gaps in knowledge.

A number of computer applications have been developed to assist in the preparation of concept and mind maps. Examples include Inspiration and MindManager which have versions that run on both Microsoft and Macintosh operating systems and allow files to be shared between them. They require students to purchase and install software, and file management within collaborative groups can be difficult and can make collaboration slow.

There is a large number of web based tools[1] that are designed to produce mind maps and concept maps. They use Java or Flash and being web-based they have the advantage of being able to be used on different platforms. Some of these tools can be downloaded and installed at no cost to students, others must be purchased. The simple tools allow users to produce maps that can be exchanged and edited.

A further enhancement to these web-based tools is a facility for synchronous use so that a group of students can share, develop and edit a map at the same time. This can be beneficial if the project team can arrange to meet at particular times, but synchronous meetings can be a problem where shift-work, travel and other and workplace (and family) demands make it difficult to schedule regular team meetings.

An alternative approach to providing support for collaboration is offered by Cmaps, concept-mapping application which allows institutions to host on a server, student concept-maps that can then be made available to and edited by all members of a project group. This allows group members to access the latest version project concept mapping files at any time, synchronously or asynchronously and ensures that the latest copy of their work is always accessible, and previous copies are backed up. These are important features for distance education collaborative project work. The Cmaps software is available at no cost for educational use. It is well supported and has been developed to Version 4 since the prototype was available in 1999 (Home page http://cmap.ihmc.us/). It uses a cross-platform Java-based application that users download to prepare and revise concept maps. Concept maps can be saved in the editable, proprietary format or be converted to non-editable graphical files should students wish to save files, incorporate their maps in documents or send maps to others.
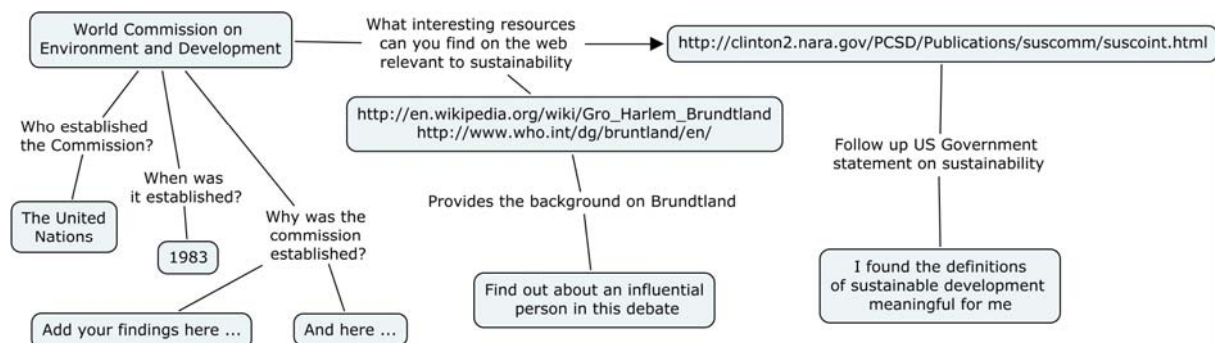

Figure 1: Example of Cmap used to ask questions and obtain answers from students

Because Cmaps provided these features, it was selected for trials to complement current use of text-based online collaborative PBL tools. The effectiveness of Cmaps will be evaluated from a technical perspective to develop an understanding of the technical support and maintenance the software and server access will require, and to determine how it can be best implemented to provide a reliable and efficient service.

Cmap trials

Cmaps is one element in the technology strategy for developing online support for distance students in engineering and built environment programs. Initial trials have focused on technical system issues, setting up the Cmaps server at CQU, testing its capacity, security and robustness, and investigating what technical difficulties remote distance education students may have in downloading, setting up and using the tools. The plan in 2007 is to test the technical aspects of Cmaps, prepare technical documentation and educational user guides for students and staff, and design selected courses to provide an environment that makes good use of the tool to support online collaborative learning and PBL activities. The use of the Cmaps will then be evaluated in 2008 to decide how to improve and expand its use if it is decided to proceed with its use.

Technical system

There are two components in the technical system, the CmapsTools Java application that each student user needs to install on their computer, and the CmapServer that CQU installs on a server so that students and groups can store, share and modify Cmaps in one location.

CmapTools is a multi-platform Java based application. Multi-platform refers to the operating systems that the application will work on i.e. Microsoft (x86), Mac OSx and PowerPC, Linux etc. Because the application is Java based it makes less demand on the student's computer processor than most other standard applications. CmapsTools requires a 54MB download via the Cmaps Website.

CmapsServer is only required if an institution wishes to establish its own web site to host student and group work. However across the world there are many public servers that can host student and group Cmaps, and students may share Cmaps by email or other file transfer methods without using a CmapsServer. CQU has chosen to set up its own CmapsServer because it can provide students with access to a Collaboration Module that allows remote students to work simultaneously on the same concept map, and it allows CQU to provide more convenient and secure student and teacher/tutor access to concept maps produced by students and project groups, and to facilitate management of group project work. To make the most effective use of concept maps, tutors need to be able to access concept maps as they are being developed, and to add comments and annotations. The CmapsServer application maintains an Active Directory (AD) of users and groups, is able to link users to a secure web interface and provide access to folders within the web interface for Cmaps. The student/group work on the server is systematically backed up. The software CmapsServer itself is a straight forward application. CQU is using Windows Server 2003 as the front end for this application and has been running this as an intranet site for staff and students. This server system is to be opened up to internet traffic after a security scan has been completed to ensure that there are no network vulnerability issues. The security scan is progressing, and nothing has been found to date that may cause security issues. Known issues have been addressed by the supplier, IHMC. The technical issues for Cmaps Tools can be viewed at http://cmap.ihmc.us/Support/issues.php. The supplier provides good support.

Technical student trials

Detailed instructions were prepared to explain to distance education students in a built environment course how to download and install CmapTools, and how to proceed with some simple concept-map construction and sharing activities. Initial feedback from students indicates that there will be problems for some students with the time it takes to download the 54Mb Java application. Students on slow connections and shared lines have been timed out and downloads have been interrupted before completion. The instructions sent to students were too long and need to be restructured to provide a summary path with links to more detailed instructions. Aside from the download time and the need to reorganise instructions, feedback was positive. Cmaps was easy to use. In addition to its use for

collaborative online learning and PBL support, it was recognised that Cmaps could be used for other purposes, to assist personal study and organise reports and assignments.

Preparation for pilot use

Technical systems needed to support Cmaps are being been tested, initial student trials outside their formal studies are underway to test the application. Preparation for pilot use with selected courses has begun. This will involve working with lecturers to incorporate use of collaborative content-mapping and text-based discussion tools in specific project based learning projects. The use of these tools will be evaluated using a framework proposed by Suh, Hasan & Couchman (2003) that assesses:

Task related interaction in collaborative, online project based learning
- How effective are the tools in accomplishing project tasks;
- How well do the tools support learners in these tasks;
- Do the tools enhance task performance with minimum effort?

Socio-emotional interaction during tasks;
- Do learners feel that the tools support development of a collaborative team spirit which improves overall task effectiveness;
- Do learners feel that the tools build the social presence of team members, the feeling that they are interacting with and getting to know each other?

This framework acknowledges that collaborative learning requires much more than just effective exchanges of information. PBL involves learners in complex, ill-founded problem-solving, it requires team members to develop a commitment to each other and to each take responsibility for building the capabilities of the team and its members (Johnson & Johnson, 1998). This is difficult enough for students learning collaboratively on-campus. Equity requires that online tools should be capable of supporting development of a productive social-emotional environment for distance education students, and teachers need to understand how best to use these tools to assist students to develop professional teamwork and communication capabilities.

Conclusion

The use of Cmaps is one of the online tools being tested in the strategy by CQU to establish virtual learning environments for its engineering and built environment programs. The vision behind the design of this online learning environment is that these programs will make available to distance education students learning experiences that simultaneously support and challenge them to learn most effectively, and engage them in the kinds of activities that productive graduates will experience in their workplaces so they will be ready to function well in complex professional work environments. Preliminary testing and trialling of the Java-based Cmaps application has begun to ascertain its potential as a robust, reliable and adaptable learning tool for students and lecturers to enable them to interact, collaborate, communicate, solve problems professionally and to demonstrate learning and understanding through collaboration in project work. The establishment of such collaborative learning environments helps support the emergence of a learning community within the program and supports students' personal development to assume a professional identity. It is an important aspect in providing a supportive and productive social-emotional environment for distance students.

Notes

1. Wikipedia provides information about the range of software tools for mind and concept mapping.

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