

# Online Computer Science Education in Australasia

M. Bower\*

*Macquarie University, Australia*

This paper reviews contemporary research literature in the area of online computer science education that has emanated from Australasia. First the literature is summarized, initially categorized by content as relating to course design, assessment, collaboration, teaching, and learning through online environments. On the basis of the themes and approaches to research that emerge from the literature, a framework for analysing online learning literature is proposed. This framework is then used to identify open areas in online computer science education research, allowing an agenda for future work to be derived.

## 1. Introduction

This paper reviews work in online teaching and learning of computer science that has taken place in Australasia. It is designed to offer readers a road map through the literature relating to teaching and learning computing online, as well as provide a framework for considering that literature. Online learning of computer science is a rapidly evolving field, and in order to provide a contemporary review only relevant literature published between 2003 and the time of writing (March 2007) has been included.

In this paper online learning is defined as any distributed learning facilitated via computer technology. The notion of distributed learning refers to learning that is in some way shared via network technologies between a cohort of students. Thus pure animation or visualization systems and stand-alone applications do not form a part of this review. As well, in order to limit the scope of this paper, intelligent tutoring systems have not been included, nor network or other simulation and modeling tools (unless they relate specifically to distributed approaches to learning). Papers focusing on the use of hardware devices such as electronic voting systems or tablet PCs have also been omitted. This paper specifically addresses educational designs that use online computing to facilitate learning.

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\*Computing Department, Building E6A, Macquarie University, Sydney, NSW 2109, Australia.  
E-mail: mbower@ics.mq.edu.au

First, the literature is reviewed, grouped under the categories of course design, assessment, collaboration, and teaching and learning environments. By classifying the reviewed literature within each category, on the basis of the approach to research and the approach to reporting, a framework for considering that literature emerges. The paper concludes by using this framework to identify an agenda for future research.

## 2. Course Design

There is a large body of Australasian literature addressing various aspects of online course design and development. These papers range from focusing upon the functional descriptions of final course designs and how to create them to those that place an emphasis upon how courses can be designed to embody a particular pedagogical approach.

### 2.1. *Functional Descriptions of Course*

A number of authors have described their online course developments principally in terms of the functional components of their final course design and their suitability for the context within which they operate. Bremer (2006) presented the way in which face-to-face approaches of an operating systems course at Otago Polytechnic were mapped to distance mode delivery using CD Rom presentations, demonstration recordings, and online quizzes, and reported positive student feedback. McCarthy and Ross (2005) described a Diploma of ICT course that used a blend of traditional and online delivery methods. These reports offer academics the capacity to compare and contrast their own approaches, both current and intended.

Other authors have focused more upon describing the design process adopted to develop their online courses (Bower, 2006a; Finegan, Tutty, & White, 2006; Gibson & Nesbit, 2006; Marshall & Mitchell, 2004). A range of development approaches adapted from other areas of design are suggested, including applying the Capability Maturity Model and the SPICE approach to software process improvement (Marshall & Mitchell, 2004), knowledge framework and systems thinking (Soft Systems Methodology) (Finegan, Tutty, & White, 2006), and the use of organizational patterns such as Belbin team roles to improve the development process (Gibson & Nesbit, 2006). Bower (2006a) described a learning system engineering approach to course design that incorporated a phase of educational research integration. This is a step towards designing courses to reflect a pedagogical approach, which is discussed in the next sub-section.

### 2.2. *Course Design Embodying an Underlying Pedagogy*

Luca (2006) discussed the role of blended learning in course delivery, and the attributes that underpin its success:

technology alone cannot provide effective and efficient solutions for teaching and learning. Solid instructional design and pedagogical approaches must be used in conjunction with blended learning for success. (p. 3)

He supported the notion of blended learning environments that are authentic, self-regulated, and promote student reflection. The following three research endeavours embody this approach.

Chan and McLoughlin (2005) described how technology was used to facilitate a balanced, blended design for an Australian IT professional masters degree. The online professional programme involved 50% industry experience, 50% coursework in an attempt to integrate relevant, situated learning with theory. In a course evaluation survey 92% of students, 100% of academics, and 83% of employers supported this blended approach.

Tolhurst and Baker (2003) described how they transformed a first year undergraduate information systems course from a traditional lecture style delivery to an approach using small group workshops, web-supported independent activities, and occasional lectures in order to overcome the diversity of student abilities and the passivity of learning using the old approach. Focus group feedback indicated that students were initially unsettled by the new approach (especially the first year students), but many identified the value of being able to self-direct their work.

Phelps and Ellis (2003) described a four year action research project to transform the linear, directive pedagogical approach of an ICT course to a more self-directed, experiential, and reflective approach. Their cyclic redevelopments incorporated an increased focus on self-efficacy, metacognition, and epistemology. They observed a decrease in student emphasis on functional issues (structure of the course, amount of reading), a reduced culture of blame, and an increase in ownership of problem solving processes. This research is an example of using a formal research design to investigate technological approaches to online computer science education.

### **3. Assessment**

One of the earliest envisaged applications of online technologies to education was the delivery of distributed assessment and feedback. Not surprisingly, there has been a large amount of research in this area. Some of this research focuses upon more pragmatic and functional aspects of an approach or tool. Others address the pedagogical alignment of the approach with learning objectives. Some research also differentiates itself by evaluating an approach or tool based on student performance, rather than student or researcher perception.

#### *3.1. Functional Aspects of Online Assessment Systems*

A number of authors have reflected upon approaches to utilizing existing online assessment tools. For instance, Roberts (2006) described a pragmatic approach to implementing formative online multiple choice quizzes in an operating systems course.

Some authors have described custom built online assessment tools, but the emphasis adopted varies considerably. Roberts and Verbyla (2003) described an

online programming assessment tool that they developed for the setting, testing, and marking of programming tasks. The emphasis of their paper is on the functionality of the tool and the approach to implementing their application. They also pointed out how their tool shelters students from several of the code development tasks normally required of programmers, allowing students to focus on the task of writing source code. On the other hand, Pisan, Richards, Sloane, Koncek, and Mitchell (2003) described a system that provides an integrated submission, automarking, and feedback suite, created using phases of requirements specification, prototyping, extended system development, and final evaluation. Their paper focuses as much upon the development process as on the functionality of the system, offering an example for teams embarking on similar educational application development projects.

### *3.2. Online Assessment Approaches Built on a Pedagogy*

Woodford and Bancroft (2004, 2005) addressed pedagogy in online assessment by analysing the level of knowledge that could be incorporated into online multiple choice questions for their IT course. They argued that by careful use of grammar, phrasing, and structure it is possible to extend beyond the typical recollection of factual levels of knowledge in Bloom's (1956) Taxonomy to test higher order levels, such as comprehension, application, and analysis.

Some authors have provided pedagogical foundations to their research by emphasizing the situatedness of their assessment systems and their alignment with overall course objectives. Prior (2003) explained how written assignments and tests do not allow students to behave as practitioners, and thus do not develop the appropriate practical skills or receive appropriate feedback. The online SQL assessment system she described can provide students with instant feedback, allowing the assessment system to become more integrated with the learning process. In a subsequent paper (Prior & Lister, 2004) the way in which Biggs' (1999) "backwash effect" applied to the learning of SQL using an online submission system was described, whereby deeper learning resulted from the alignment of prescribed outcomes, grading practices, and teaching and learning activities. Feedback from students indicated that 85% of students preferred the online approach to SQL assessment, as opposed to a written approach. The majority of students in focus groups also indicated that the online assessment system influenced the way they went about learning SQL, encouraging them to practice more often.

Solomon, Santamaria, and Lister (2006) also emphasized the situatedness of their custom-built assessment tool. Their LinuxGym application randomly generates and then automarks Linux scripting tasks. Their approach is also situated to the extent that it provides students with feedback in accomplishing the actual programming process they are expected to master. By utilizing smaller but more numerous tasks than the assignment approach used in other courses, students are provided with a larger number of feedback loops. The authors report significantly lower failure rates as a result of adopting LinuxGym on their course, as well as improved student satisfaction.

### 3.3. Online Assessment to Support Knowledge Construction

Sadiq, Orlowska, Sadiq, and Lin (2004) described an online SQL assessment system (SQLator) developed at the University of Queensland. While their paper predominantly discussed the architecture and functionality of the system, the authors also showed how cognitive and collaborative features are integrated into the system, such as the capacity for students to make formative notes and to correspond with the lecturer from within the system. They noted that implementing SQLator resulted in improved student performance in the SQL component of examinations.

Kay, Li, and Fekete (2007) presented an integrated learning and assessment system that focuses on developing higher level reflective and critical thinking at the same time as students develop foundational programming skills. The authors described their Reflect system, which allows students to both “reflect-in-action” and “reflect-on-action” (Schön, 1987). Students are presented with learning objectives, marking criteria, and a potentially flawed solution. They are then provided with feedback regarding their assessment of the solution as compared with the teachers. Students are then asked to submit their model solution to the problem and rate their own performance (reflection-in-action). Students are also provided with an individual user profile which displays their progress on a concept by concept basis, allowing them to perform an “overall reflection-on-action”. The authors’ also made an effort to evaluate the system based on student performance data, with results indicating higher course achievers used the tool more comprehensively than borderline pass students.

### 3.4. Evaluation of Online Assessment

Some researchers have adopted a formal methodology to gauge the efficacy of their assessment tools. Raben and Litchfield (2006) presented a tool that facilitates peer allocation of marks for students undertaking group software engineering projects. They found that intra-team peer assessment of performance conducted on a regular basis throughout the project resulted in a far greater distribution of marks than when only a summative peer assessment was performed.

Blumenstein, Green, Nguyen, and Muthukkumarasamy (2004) used a formal experimental design to investigate the extent to which their automated marking tool matched manual grading of subjective aspects of programs. Their research used an experimental design to compare the marks allocated by their system for students’ formatting, programming style, and commenting (as well as more objective aspects such as compilation and execution) to that of a human marker. They found that in two out of their three trials their system matched the programming style grade the human marker allocated to students in over 75% of cases, which was a more reliable matching than for the compilation and execution marks.

Note that Solomon et al. (2006), Sadiq et al. (2004), and Kay et al. (2007) also adopted a formal research methodology to evaluate the efficacy of their approaches by measuring changes in student performance.

## 4. Collaboration

Collaboration forms the basis of several theories of learning, including Socio-constructivism (Vygotsky, 1978), Communities of Practice (Wenger, 1998) and Activity Theory (Engeström, 1987). It is not surprising that the ability of network technologies to facilitate collaboration has resulted in a wide variety of research, with the focus ranging from functional aspects of implementation to the analysis of data collected to form understandings of online collaboration to approaches to using collaboration to support knowledge construction.

### 4.1. *Functional Descriptions of Online Collaboration*

Egea (2003) presented a purpose-built tool to support the management of virtual teams. She described how providing different views for course coordinators, campus administrators, markers, and students allowed for a consistent implementation of a large-scale course.

Sheard and colleagues investigated the use of discussion boards on different levels. On a pragmatic level the staff perspective of managing web-based discussion forums was described (Sheard, Miller, & Ramakrishnan, 2003). The authors' survey of staff using discussion forums highlighted the need for careful management to avoid unreasonable staff workloads. These researchers also analysed the learning artifacts from students' use of online discussion boards, as described below.

### 4.2. *Analysis of Online Collaboration*

In their subsequent work Sheard and colleagues (Sheard, 2004; Sheard, Ramakrishnan, & Miller, 2003) developed a model to describe the nature of "electronic learning communities" that used discussion forums, based on data collected from students, as well as tutorial staff and lecturers, across eight different computing subjects. Their model explained how the type of learning depends on the degree of proactive or reactive behaviour of teaching staff and students. They distinguished between electronic learning communities and an "online help desk" as the extent to which students are responding to other students' questions as opposed to teachers. This is a move towards using a research approach to explaining the interaction between technology, collaboration, and learning.

Clear and Kassabova (2005) also developed a data-driven model of collaborative learning. Their research investigated motivational patterns observed in Global Virtual Teams (GVTs) comprised of students from Auckland University of Technology and Uppsala University, Sweden. Based on the underlying pedagogy of motivation theory, they proposed three new patterns of motivation that emerged from their analysis of three semesters of data: "committed and satisfied," "committed and unhappy," and "others' commitment matters." They describe how the meaningfulness of direction, relevance, and task prescription are being addressed to improve the overall meaningfulness of the task, in an attempt to improve motivation in the GVTs.

At Macquarie University two separate research endeavours, both involving wikis, adopted data-driven approaches to investigating teaching and learning. One of the projects analysed the effect of different online learning activities upon student collaborations in the wikis (Bower, Woo, Roberts, & Watters, 2006). Two learning designs (weekly extension activities versus semester-long group projects) were compared and contrasted in two courses, using different wiki platforms. The authors analysed and interpreted contributions and feedback data, which led to a set of design principles for using wikis for collaborative learning. The other Macquarie project investigated how the mode of online collaboration affects concept formation, and is described in the following section.

#### *4.3. Knowledge Construction and Reflective Thinking in Collaborative Learning*

In a comparison of asynchronous concept building (using wikis), synchronous knowledge construction (using a web conferencing system), and independent study approaches Bower (2007b) analysed how different online collaborative approaches affect discourse and concept formation. The type of solutions and discourse arising from the various approaches were categorized, revealing how synchronous collaboration tools required greater amounts of discussion to coordinate activity, but also resulted in more collaboration relating to conceptual development.

Other researchers have placed the emphasis on how their online collaborative tools can be used to promote reflective thinking practices. Hamer, Kell, and Spence (2007) presented an asynchronous peer review tool (Aropä) for promoting reflective thinking on content. The authors noted that requiring students to inspect one another's code provides them with exposure to quality code, as well as allowing them to learn from their mistakes. Kay, Maisonneuve, Yacef, and Reimann (2006) presented a set of tools that support visualization of the Salas, Sims, and Burke (2005) "Big Five" theory of teamwork (leadership, mutual performance monitoring, back-up behaviour, adaptability, group mindset), thus promoting reflective thinking on collaborative skills. Their visualizations can be automatically generated from records of student interactions in the TRAC system, which is an open source system that allows software development teams to allocate tasks between group members, to share files, and to collaborate via a wiki. The authors described how the "activity radars," "interaction networks," and the novel "wattle tree" timeline visualizations relate to each of the Big Five teamwork factors. Of all the literature surveyed this was the only paper that described a complementary set of tools and paradigms to support the development of both the students' domain knowledge and collaboration skills.

### **5. Literature Considering the Process of Teaching Computing Online**

This category relates to the activity of teaching online, from tools and approaches for managing courses to various online learning designs. Many papers present experiential accounts, concerned with either tools used or learning activities applied.

Others adopt a more formal approach to researching their teaching activities, involving the collection and analysis of learning data.

### *5.1. Experiential Accounts of Teaching Online*

Several authors have provided evaluations of and recommendations for teaching computing online based on their personal experiences. For instance, reviews of learning management systems (LMS) have discussed issues such as the technical difficulties that arise when trying to accomplish pedagogical aims (Solomon, 2003), or the efficacy and migration issues associated with using open source systems such as Moodle (Bremer & Bryant, 2005; Corich, 2005). On the basis of their experiences Young and McSporran (2004) provided pragmatic recommendations for using LMSs and promoting student participation. Hart (2005) discussed attitudinal aspects of teaching computing online, observing how aspects of implementation detracted from the motivation of adult learners in a low socio-economic area of Auckland to complete web-based ICT training.

Other articles have focused more upon particular online learning activities. For instance, Barker (2003) described a learning design that used a discussion board to simulate interactions between a database system development team (students) and a business client (teacher) to elicit requirements beyond those made available from business report documents. Based on a survey of 85 students, 82% felt this adequately simulated a real-life business situation, and 90% valued the discussion board as a learning tool, although 65% would have preferred to be able to meet the “business” face to face as well as online. Brereton, Donovan, and Viller (2003) described an activity requiring students to engage in face to face activities (watching videos, proposing themes of interaction in pairs, comparing themes to other groups) and then reporting on their themes using a wiki. The Wikiweb supported a reflective approach to reporting, collaborative authoring, and peer feedback.

Bower has investigated synchronous online learning activities in virtual classrooms (Bower, 2006b, 2007a; Bower & Richards, 2005a). This research discussed how task type, tool selection, interface design, and pedagogic strategies affect learning. The impact of students’ online collaborative skills on their ability to engage in active learning tasks is discussed, and recommendations for teaching in synchronous collaborative spaces are proposed.

Some researchers describe custom-built tools for teaching and learning. Truong, Bancroft, and Roe (2005) presented an intelligent programming environment that scaffolds introductory computing students by providing applet-based fill in the gap programming exercises. The authors explained how their Environment for Learning to Program (ELP) supported novice learners by reducing the complexity of the programming tasks and also by providing greater levels of feedback. The authors noted that 60% of second year students surveyed were positive about ELP.

Other research has focused on describing different approaches to online instruction. Dargie and Snell-Siddle (2006) explained an approach to creating web-based multimedia presentations. Small sample results from a student survey



regarding the efficacy of their approach indicated that the majority of students would be likely to use such resources and that these resources would enhance their learning experience.

### *5.2. Structured Research Investigating Online Teaching Approaches*

Some papers have adopted a more formal methodological approach towards analysing the efficacy of their online teaching approaches. Like Dargie and Snell-Siddle (2006), Bower and Richards (2005b) researched the efficacy of web-based multimedia instructional delivery. However, they used a formal treatment and control design to compare their online approach to a standard text-based delivery. They found that their computing students at Macquarie University took significantly longer to complete the multimedia version of the learning materials, yet expressed a significant preference for it.

Tolhurst (2004) also adopted a formal research approach to gauging how restructuring an introductory information systems subject affected the students' epistemology. Student scores improved on several dimensions of Hofer's Domain Focused Epistemological Beliefs Questionnaire.

## **6. Online Learning Environments**

The final category of online computer science education considered in this paper describes how students interact with and learn through online learning environments. The work by Ceddia, Sheard, and Tibbey (2007) and Kay, Maisonneuve, Yacef, and Zaiane (2006) harvested learning data to analyse how students interact with online platforms, while the work on Adaptive Learning Environments by Slay, Quirchmayr, Kurzel, and Hagenus (2003) and Wolf (2003) considered how environments can be designed to account for individual differences in approaches to constructing understanding.

### *6.1. Analysing Student Interactions with Learning Environments*

Ceddia et al. (2007) presented a Weblog Analysis Tool (WAT) that allows an educator to analyse the user interactions in web site log files to determine whether students completed learning activities. The authors defined five types of learning activities related to the learning objectives of the course (presentational, organizational, explorational, goal-focused, and complex) and then used WAT to extract information regarding completion rates, efficiency of goal-focused activities, whether explorational activities were purposeful or undirected, unusual or outlying results that may indicate problems with the interface or learning activity, and so on. In this way WAT provides insights into the learning behaviour of students throughout the course, as well as providing feedback on student accomplishments. Thus WAT enables educators to acquire a deeper understanding of the learner, the technology, and their own pedagogy.

Kay, Maisonneuve, Yacef, and Zaiane (2006) also presented approaches for understanding how students learn through online facilities. They described techniques for mining student collaboration logs from the TRAC open source software development tool. The authors described their approaches to interrogating the log data to determine patterns of interaction, which were analysed both by temporal sequence (or “sessions”) and by activity on particular resources. The results from their analysis of ten teams indicated that better performance was correlated with more authors contributing per session, a greater number of resources being created, and fewer days over which a resource was modified (all of which was collected by their data mining approaches). The authors also pointed out that the approaches they were developing had bidirectional use—to track group performance in large classes and also to reveal to academics the qualities of effective team performance.

### *6.2. Adaptive Learning Environments*

There has been some Australasian work in the field of adaptive learning environments, which take into account individual differences in how students learn. Slay et al. (2003) described the architecture, interface, content, and administration of their Adaptive Multimedia Learning Environment (AMLE), which delivers course structure and assessment that is personalized to a student’s profile. Wolf (2003) described an adaptive learning environment that delivers resources to suit the media experiences and learning styles of the students, a move towards accounting for the way students construct their knowledge. For instance, rich text, pictures, “interactivelets,” or audio resources are presented depending on whether the student has textual, visual, kinesthetic, or auditory preferences. These approaches are an example of how online learning research and development can take into account differences in student cognition and approaches to knowledge construction.

## **7. Framework for Analysis**

In the literature reviewed three themes emerge, forming a framework of analysis. These three dimensions broadly relate to the degree of pedagogy, the approach to considering student learning, and the method of evaluation adopted as follows:

- functional versus pedagogical—some papers focus on functional and pragmatic issues while other papers are based in educational theory;
- learning outcome versus learning process—some of the literature focuses on outcomes of learning while other research is concerned with how students think and learn;
- experiential versus methodological—some research is based upon perceptions of academics and students while other studies adopt research designs that analyse learning data.

Table 1. Classifying studies by degree of pedagogical underpinnings, learning outcome/process, and research methodology

	Experiential				Methodological				Totals
	Functional outcome	Pedagogical outcome	Functional process	Pedagogical process	Functional outcome	Pedagogical outcome	Functional process	Pedagogical process	
Course design	5	2	1			1			9
Assessment	3	2			2	1	1	1	10
Collaboration	2			2	2	1	1		8
Teaching Environment	8	1			2	1			12
Totals	18	5	2	3	8	4	2	1	43

To determine trends in the type of research being conducted the studies reviewed in this paper were classified by their position on all three of the above dimensions. The results are shown in Table 1.

In cases where a study could be considered as falling into more than one category the study was categorized according to its primary emphasis. While such an approach cannot be considered precise in every instance, the results achieved serve to indicate general trends in research.

## 8. Future Directions

An interpretation of the above results implies a research agenda for online computer science education that includes the following.

- More research to formally evaluate online course design and delivery approaches—there is little work on validating methodologies and course structures.
- Formal investigation of the interplay between online technologies and cognition—only three studies in total adopted a methodological approach to investigating how online technologies can be used to effect the construction of knowledge. Multimedia Learning Theory (Mayer, 2005) and Cognitive Load Theory (van Merriënboer & Ayres, 2005) are useful fields to support this endeavour.
- More studies observing the way in which students form mental models using (collaborative) online technologies—the absence of any functional–process–experiential studies in the collaboration and teaching categories indicates an opportunity for research that observes how students use the affordances of technologies to negotiate shared meanings. Distributed Cognition Theory (Hollan, Hutchins, & Kirsh, 2000) offers a framework for this.

The classification in Table 1 also reveals a strong representation of functional–outcome–experiential studies of online learning. To this extent researchers are encouraged to shift to more pedagogical, learning process, and methodological approaches.

## 9. Conclusion

An analysis of the computer science education online learning literature emanating from Australasia has revealed a variety of research along a number of dimensions, which has then been used to create a framework for analysis of online learning. The framework has in turn been used to identify opportunities for future research. Servicing this agenda will allow computer science educators to broaden our understanding of the impact that technology-based learning produces.

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