1-1-2006

Identifying the Challenges in Teaching Computer Science Topics Online

Yuwanuch Gulatee
Edith Cowan University

Barbara Combes
Edith Cowan University

Gulatee, Y. and Combes, B. Edith Cowan University, Australia. Identifying the Challenges in Teaching Computer Science Topics Online

Yuwanuch Gulatee1 and Barbara Combes2

[1]School of Computer and Information Science
Edith Cowan University, Australia,
E-mail: ygulatee@student.ecu.edu.au

[2]School of Computer and Information Science
Edith Cowan University, Australia,
E-mail: b.combes@ecu.edu.au

ABSTRACT

In an attempt to provide educational opportunities for students who are working or who are located at a distance, many universities have developed wholly online distance education programs. These online courses use web technology as a distributed learning mechanism. However, online distance learning in Computer Science courses remains challenging for both teachers and students. Research has shown that there is a significant risk factor for online courses in Computer Science. Course developers and teachers need to be aware of the particular needs of Computer Science students when establishing online courses, if they wish to graduate successful and satisfied students. This paper aims to identify some of the challenges in teaching Computer Science topics online, and identify useful support strategies to enhance learning through the informed use of web-based elearning.

INTRODUCTION

Over the last few years, web technology has been adopted to assist learners with real-time studying at a distance. Consequently, web delivery has grown rapidly and has been used as a vehicle for learning. The research of Kim, Bonk, and Zeng (2005) shows that 'elearning has become an increasingly important delivery format and may even dominate training in the near future'. A similar finding by Tanaka (2005) indicates that in the 1990s and the first half of this decade, people will be more focused on web-based elearning to improve their skills. However, for distance learning in the field of Computer Science, topics such as programming, database design and artificial intelligence (AI) remain challenging and require further development. Sheard, Macdonald, and Hagan (1997) found that computer programming courses are more difficult and time consuming than other courses for the majority of students. Deek and Espinosa (2005) believe that studying subjects such as programming languages are difficult because they have been designed without attention to human-computer interaction. Many Computer Science subjects are potentially highly technical in nature, which may be hard for students to learn independently in a fully online environment. Thus, the question that needs to be addressed is: how do we teach these Computer Science courses online? This paper aims to identify some of the challenges in teaching Computer Science topics online and identify useful support strategies to enhance learning through the informed use of web-based elearning.

BACKGROUND

Distance learning became popular in the 1970s and 1980s, but was generally conducted via postal mail until relatively recently. The changing nature of teaching in distance education since the 1990s has been driven by developments in technology. This has meant a move from the delivery of print

copies of the traditional 'chalk and talk' lecture, to computer based learning systems (LMS) (McSporran & King, 2005). Since the mid to late1990s, the World Wide Web has been used as a distributed learning mechanism, enhancing the digital learning environment to support online students. Using this delivery mode teachers can provide a range of resources such as discussion forums and chat, multimedia, videoconferencing, audio and electronic blackboards to communicate and teach their students (Lee, 2004).These changes in distance education have developed in an attempt to provide easier access to educational opportunities for students who are located remotely from the university, who are working or who have other constraints/commitments such as families/young children. Kazmer and Haythornthwaite (2005, p.7) found that in the US 'in the academic year 2001-2, five million people took at least one course online, and three million were enrolled in online degree programs.' Distance education online has become a popular alternative to face-to-face instruction. While there have been strong indications that the promise of online delivery is not as revolutionary as first predicted (Werry, 2002), online courses are still popular with students and universities. The opportunities presented by emerging technologies to create quality, new learning environments that provide convenience for learners, who live a long way from the university and/or have to work at the same time, has been recognized by tertiary educational institutions worldwide. Therefore, investigating the challenges of teaching Computer Science topics in an online environment is critical for teachers and universities offering these courses using flexible delivery modes.

WHY IS COMPUTER SCIENCE DIFFERENT?

Computer Science courses such as programming, database development and artificial intelligence (AI), are more difficult to teach and learn than other courses in a wholly online environment (Linschner, 2002), because students are required to develop a range of technical and practical skills and conceptual understandings, in order to be able to apply this knowledge to different applications and workplace challenges. Research shows that students in programming courses have difficulty visualizing abstract concepts (McSporran & King,2005). Emerging research on the use of learning objects to teach AI indicates that deep learning at conceptual, technical and practical levels only occurs when students have opportunities to visualize and engage practically with their programming. In this case an animated AI toolkit allows students to visualize how the underlying code translates into an animated game sequence via an animated display of the internal workings of their controllers, provided by the AI toolkit. 'Students can visualize and experience the results of their program on two levels: the programming in action and operationally as a finished product in the game' (Hingston, Combes & Masek, 2006).

Computer Science is recognized as an area of instruction that requires complex conceptual knowledge and understandings, and is potentially both highly technical and practical in nature. The understanding of essential abstract concepts that underpin the development of a 'programming mindset' present more challenges to teaching and learning than in other courses (Jehng & Chan, 1998). Students in Computer Science learning programming as a subject, must develop competence in several cognitive areas such as syntactic knowledge and conceptual knowledge (Linschner, 2002). They then need to develop strategies and utilize their problem-solving skills to creatively solve programming problems or to create new programs (Bayman & Mayer, 1998). McSporran and King (2005) maintain that cognitive development and the development of conceptual understandings rarely occurs in an isolated environment. Hence, studying Computer Science topics in an online environment is very difficult for the students who may be studying in isolation. Programming languages have a highly technical syntax, with complex rules. Like all language learning, computer programming languages are difficult to learn and understand (Linschner, 2002). In their research, Deek and Espinosa (2005) found that most novice programmers find introductory programming courses frustrating and difficult to learn.

Research by McSporran and King (2005) indicates that in online programming classes, students find it more difficult to understand complex concepts, technical knowledge and applications of the theory of programming to problem-solving exercises than on campus students, who have the benefit of face-to-face feedback from their teachers and peers. These findings are also supported by the work of Hentea, Shea & Pennington (2003) who showed that for technical subjects, teachers

need to interact more with students, to assist them with problem-solving and to seek new sources of information to avoid limiting their capacity to apply theory to practice. Therefore, Computer Science students, particularly those working in programming subjects, are at significant risk when attempting an online course compared to traditional classroom students. Best practice teaching and learning in Computer Science subjects requires students to learn collaboratively in an interactive environment which mimics the workplace; to use a variety of technologies and learning tools; to participate in active learning to develop technical skills and knowledge; and to engage in conceptual discussions with their peers and teachers to become active problem-solvers (Yang & Liu, 2004).

Therefore, it can be concluded that Computer Science courses, particularly those which include programming units, are more challenging for students. To develop competence, students are required to acquire complex, conceptual understandings, while learning the highly technical components of a scripting language, which they then must practically implement to solve a programming problem and thus produce a program that works. In other areas of Computer Science, such as AI, students also must have an understanding of physics, fuzzy logic, evolutionary computation and artificial neural networks (Hingston, Combes & Masek, 2006). Even in a face-to-face teaching-learning environment, students find these units extremely challenging. In the online environment, where the student is physically isolated and where none of the body language and ready/immediate access to the teacher's knowledge at the point of need is available, teaching and learning becomes even more difficult.

CHALLENGES IN TEACHING AND LEARNING ONLINE

Synchronous versus asynchronous communication

The first challenge in teaching Computer Science topics online is the application of the theory and practice of classroom-based courses into the online environment. A major factor identified in the research on the online delivery of course materials, is the problem caused by a lack of interaction between the teacher and the student/s that is a feature of face-to-face classroom teaching (Hentea, Shea, & Pennington, 2003). For technical subjects in Computer Science such as computer programming, database design and AI, this lack of interaction is exacerbated. In Computer Science subjects, the teaching requires a high level of communication between students and the teacher. In the online environment where students may be located at a great distance and studying in isolation (for example, outback Australia), interaction may be synchronous (real time) or asynchronous (any time).

Asynchronous methods use collaborative tools that enable students to communicate with their teacher and their peers at any time. For example, email and discussion forums (bulletin boards) are both asynchronous methods of communication. Email is used widely and is one of the simplest forms of asynchronous communication technology, and can be used for teacher-student communication and student-student exchanges. Discussion forums can also be used for distance education, and provide a centralized mechanism for discussion on specific course topics where everyone is included, as well as informal exchanges (Neal & Miller, 2005). Midkiff and DaSilva (2006) identified the benefits of using asynchronous communications as: flexibility for the users, the ability to engage with different text documents, and the sharing of file attachments. Another advantage of the asynchronous environment is that students can use it any time and any where. Students who opt to complete their studies online due to work or family commitments, often value this flexibility highly (Combes & Anderson, 2006). According to Goldsmith (2001) students tend to have different attitudes toward asynchronous communications. Most students report positively about the flexibility, the choice to manage their own time and learning space, and the facility for detailed feedback. The major negative aspect reported by students is lack of interaction.

Synchronous communication technologies provide opportunities for online students and teachers to interact in real time. These real-time technologies may include audio and video, text and chat room, electronic whiteboards and screen sharing. These technologies provide students with two-way, interactive communication (Ciocco, Toporski & Dorris, 2005). The benefit of a synchronous learning environment is that it provides immediate interaction and can mimic that immediate feedback loop

that is provided in a face-to-face classroom. Gibson, Blackwell, & Hodgetts (1998) found that synchronous communication is an effective online communication tool. It allows the students to ask questions and get feedback in real time like the students in the on campus classroom. However, there are also some disadvantages to synchronous communications. Learners all need to log in at the same time as their teachers or peers (Sanders & Morrison-Shetlar, 2001), which is a problem when students are located in different international time zones and where working schedules or family commitments may create 'attendance' problems for online students. Synchronous communications also reduce the flexibility that is a feature of online learning. Some researchers recommend 'keep your life simple and stick to asynchronous communication' (Gibson, Blackwell, & Hodgetts, 1998, p.280).

So while asynchronous and synchronous communication technologies do provide opportunities for teacher-student and student-student interaction, they do not replace or effectively simulate the face-to-face environment. The most commonly used of these technologies (email, discussion forums and chat) still depend on using text as a means of communication. Communicating by text is an imperfect medium for communication when the participants do not have the added value of body language and intonation to guide understanding and meaning. While videoconferencing and streaming video help to alleviate this problem, many students who are studying remotely do not have ready access to fast bandwidths or the technology to enable them the use of these communications technologies easily. Students studying wholly online often experience increased levels of frustration, anxiety, lack confidence, feelings of isolation and a lack of connectedness (Combes & Anderson, 2006). For Computer Science students, where the interactive nature of the teaching and learning often determines whether students master technical and practical skills, and develop complex conceptual understandings, learning in an online environment dominated by text is very difficult. So while asynchronous and synchronous communications go part of the way towards solving some of these issues, they do not provide conclusive solutions to the problems of teacher/student and peer-to-peer interaction and immediate feedback that are features of the on campus experience.

Teaching and learning online

Teaching Computer Science courses online also impacts on the students' learning styles. Research shows that while learning styles don't necessarily influence the ways students interact with media, the teacher or other learners, they do affect student satisfaction, particularly activities involving class discussions and group/team work (Benty-Marom, Saporta & Caspi, 2005). Learning environments, particularly those based around text as a delivery mode, may suit some students, but they do not cater for all learners. For example, an analysis of Sanders and Morrison-Shetlar's (2001) work shows that their students preferred to talk to people in person rather than communicate with them through the chat room on the Web. However, they were comfortable working with the content online. This result indicates that while students may be happy with using the online learning approach to access content, they do prefer to communicate face-to-face. These learners may have had a preference for learning using interaction and an auditory style, rather than in isolation and by abstract symbols or text.

Understanding the preferred learning styles of students and catering for all learning styles (abstract/text, auditory, visual and kinesthetic/tactile) is important for deep learning and student satisfaction. Research by Meisalo, Sutinen and Torvinen (2002) indicates that teaching-learning methods delivered in a virtual classroom impact on student success. They recommend a blend of methods be used to cater for all learning styles, both in the virtual and the online classroom. This is especially important in the online environment, where there is none of the face-to-face communication, audio and visual interaction. A number of researchers have also indicated that courses in an online environment are more challenging to manage, because the delivery method needs to offer strong support from teachers (Meisalo, Sutinen & Torvinen, 2002; Combes & Anderson, 2006). Students working online in isolation suffer from feelings of anxiety, lack of confidence and frustration. Major problems for students studying Computer Science courses online include lack of time, difficult exercises and a lack of consistent and constant support from teachers. Students prefer to study difficult Computer Science units face-to-face with their teacher, rather than via the Internet (Meisalo, Sutinen, & Torvinen, 2002).

While catering for learning styles is important in all teaching-learning environments, it is especially important in the online environment. Computer Science subjects require teachers to deliver information using a range of learning styles. Computer Science students must be able to master complex text, symbolic language and syntax; they need to be able to visualize solutions to problems and develop schematic designs for programming solutions; and they need to develop practical skills to input data, skim and scan code on a screen and write a program that works according to the specified requirements. Computer Science students may have a preferred learning style, but to become proficient in areas such as programming, database design and AI, they must also develop a range of skills across learning styles. While audio, text and visuals, including animation can be provided in the online environment, students still find this skill development very challenging.

OTHER CHALLENGES

Another major issue when teaching online courses, is the large number of students in some online classes. Large student numbers increase the difficulty of keeping constant and consistent communication channels open with students. Teachers may not be able to provide the personalized support that is a feature of face-to-face classrooms to all students in large online classes. The nature of the online environment means that students requiring immediate assistance to correct a misunderstanding may not receive it, especially where asynchronous communication is being used. Yang & Liu, (2004) reported that while learners think that online content is a very useful facility, they do not like using the virtual classroom as their main educational delivery mode, because they don't believe the online learning environment can effectively simulate or replace face-to-face communication and the interaction that group/team discussions provide. Students preferred to use an online learning environment as a guide and management tool for their study, and as a context where they can study in their own time rather than as a replacement for the classroom. Raymond et al.(2005) found that using asynchronous learning environments is not interactive enough, whereas the use of synchronous learning environments provided more interaction between students and professors. Synchronous and asynchronous communications are also time consuming for teachers and students, particularly in large classes where there may be many messages to read.

Other issues for students working in an online environment are problems with technology, ISP services and bandwidth (Combes & Anderson, 2006). Another issue involves the cost of learning online. Students require sophisticated equipment, robust access and a good knowledge of a range of software. Online courses also tend to shift the cost of printing course materials back onto the students, as everything is supplied electronically. While these issues are often beyond the scope of the lecturer, they often impact on student satisfaction, introduce frustration and affect student motivation to study or even continue the course (Combes & Anderson, 2006). For students studying Computer Science courses, these additional issues may become overwhelming. These findings are significant for course development and the management of online courses.

TEACHING COMPUTER SCIENCE ONLINE

If we recognize that teaching some aspects of Computer Science is more challenging, especially in the online environment, then what do teachers and course developers need to consider when creating online units? Howell et al (2003) demonstrated that good education should provide a range of alternative tools and learning options to support students. This is particularly relevant in the virtual classroom where students are physically isolated and may only communicate with their teachers and peers via text. Therefore, the best practice, online delivery model should include a range of student resources, facilitator resources and facilitator support. These researchers maintain that student resources should include online course material, discussion groups, real time lectures, learning guidelines, textbooks and facilitator notes (Howell et al, 2003). If the technology allows, we could also include low bandwidth images and animated graphics, audio, web-based simulations and multimedia presentations to cater for the auditory and visual learners.

Some learners believe that they can express themselves more clearly with face-to-face communication (Goldsmith, 2001) even though they prefer the flexibility of asynchronous. In a wholly online environment, course developers should provide both asynchronous and synchronous communications to cater for everyone. Since working online is time consuming, it is important for teachers to monitor the amount of work required to complete online workshops that include a discussion or chat. In Computer Science units that require active learning and the development of technical and practical skills using hardware and a range of software, problem-solving and conceptual understandings; using both types of communications technology, will go some way towards replicating the face-to-face classroom experience. In courses which are wholly online, the course materials must not only provide access to content, but they must also motivate students, support and enhance the learning experience. This is particularly relevant for online Computer Science courses.

Best practice online courses also provide elearning activities and tasks that are assessed in appropriate ways. Assessments should be authentic and reflect the current workplace (Alexander, 2001). Students need to receive prompt and useful feedback on their work, and the assessments should reflect the learning objectives of the course. While these recommendations are appropriate for all courses, they are particularly relevant to the virtual environment. Students who are online and isolated from the physical classroom, their teacher and peers, need to be clear about what they have to do to successfully pass the unit. This requires constant and consistent monitoring by the teacher and opportunities for teacher-student interaction.

CONCLUSION

From the previous discussion it appears that learning Computer Science courses in an online environment does provide more challenges for the teacher and the student. Computer Science subjects, by their nature, involve complex conceptual understandings, the acquisition of basic knowledge, highly technical terms and problem-solving skills. Students also need to have proficiency in technical and practical skills with a range of hardware and software. Research evidence also indicates that before providing an online course, teachers should understand the learning styles of their prospective students, because learning styles influence student satisfaction with activities involving interactive learning and communication. Communication and collaborative learning play an important role in the online learning environment. Moreover, Computer Science courses must include strong collaborative learning opportunities between students, their peers and teachers to develop problem-solving skills and apply complex theory to practical applications.

Managing collaborative learning environments requires the teacher to provide a range of appropriate learning content/objects and delivery modes. The online environment should provide rich support, effective and alternative tools and a range of options designed to support student learning. Learning resources such as course materials, learning guidelines, course activities and facilitator support are essential components. The technologies for delivery should include synchronous and asynchronous communication to cater for all students. In situations where face-to-face are not possible, the inclusion of low bandwidth, simulations and animations will provide students with a more supportive learning environment. This is especially true in Computer Science where a demonstration of a practical application is often the best way to convey meaning for students. Issues such as cost, time management and the size of the class need to be addressed when providing courses online. Class size affects the capacity of the teacher to respond consistently and in a timely manner and to monitor student learning. Class size also affects the students who may have difficulty managing the volume of communication and materials provided for their study. Research has shown that there is a significant risk factor for online courses in Computer Science. Course developers and teachers need to be aware of the particular needs of Computer Science students when establishing online courses, if they wish to graduate successful and satisfied students.

REFERENCES

Alexander, S. (2001). Elearning Developments and Experiences. Education + Training, 43, pp. 240-248.

Bayman, P. and Mayer, R.E. (1988). Using Conceptual Models to Teach Basic Computer Programming. Journal of Education Psychology, 80(3), pp. 291-298.

Benty-Marom, R., Saporta, K. and Caspi, A. (2005). Synchronous vs. Asynchronous Tutorials: Factors Affecting Students' Preferences and Choices. Journal of Research on Technology in Education, 37(3), pp. 245-262.

Ciocco, M.D., Toporski, N. and Dorris, M. (2005). Developing a Synchronous Web Seminar Application for Online Learning. Paper presented at the Proceedings of the 33rd Annual ACM SIGUCCS Conference on User services, Monterey, CA, USA.

Combes. B. and Anderson, K. (2006). Supporting First Year E-learners in Courses for the Information Professions. Proceedings of the Asia-Pacific Conference on Library & Information Education and Practice (A-LIEP) 2006: Preparing Information Professionals for Leadership in the New Age, Singapore, 3-6 April 2006, pp. 587-597.

Deek, F.P. and Espinosa, I. (2005). An Evolving Approach to Learning Problem Solving and Program Development: The Distributed Learning Model. International Journal on Elearning 4(4), pp. 409-426.

Gibson, J.W., Blackwell, C.W. and Hodgetts, R.M. (1998). Communicating with Online Students: Lessons from the Front. IEEE, 2, pp. 277-284.

Goldsmith, D.J. (2001). Communication, Humour, and Personality : Students 's Attitudes to Learning Online. (Statistical Data Included). Academic Exchange Quarterly.

Hentea, M., Shea, M.J. and Pennington, L. (2003). A Perspective on Fulfilling the Expectation of Distance Education. Paper Presented at the Proceeding of the 4th Conference on Information Technology curriculum, New York, USA.

Hingston, P., Combes, B. and Masek, M. (2006). Teaching an Undergraduate AI Course with Games and Simulation. Edutainment 2006, International Conference on Elearning and Games, April 16-19, 2006, Zhejiang University, Hangzhou, China.

Howell, S., Harris, M.C., Wikinson, S.A. and Zuluaga, C. (2003). Teaching Mixed-Mode: A case study in remote deliverly of Computer Science in Africa. Education Media International, pp. 297-306.

Jehng, J.J. and Chan, T. (1998). Design Computer Support for Collaborative Virtual Learning in the Domain of Computer Programming. Computer in Human Behaviour, 14(3), pp. 429-448.

Kazmer, M.M. & Haythornthwaite, C. (2005). Multiple Perspectives on Online Learning. ACM Press, 25(1), pp. 7-11.

Kim, K.J., Bonk, C.J. and Zeng, T. (2005, June). Surveying the Future of Workplace Elearning: The Rise of Blending, Interactivity, and Authentic Learning. E-Learn Magazine. Retrieved 6 Nov 2006 from http://www.elearnmag.org/subpage.cfm?section=research&article=5-1

Lee, A. (2004). Does the Development of Web-based Learning System Signal the End for Traditional Classroom Education? Retrieved 9, 2006, from http://www.silktide.com/articles/our-articles/web-based-learning-vs-traditional.

Linschner, R. (2002). Programming Language and Tools for Deep Learning [Electronic Version]. Retrieved 18 May 2006 from: http://www.cs.utexas.edu/users/csed/doc_consortium/DC99/lischner-abstract.html.

McSporran, M. and King, C. (2005). Blended Is Better: Choosing Educational Delivery Methods. Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications, Montreal, Canada.

Meisalo, V., Sutinen, E. and Torvinen, S. (2002). How to Improve a Virtual Programming Course. Frontiers in Education, FIE 2002, 1.

Midkiff, S.F. and DaSilva, L.A. (2006). Leveraging the Web for Synchronous Versus Asynchronous Distance Learning [Electronic Version]. Retrieved 29 Aug 2006 from www.shockandawe.us/mscis/313/Midkiff.pdf

Neal, L. and Miller, D. (2005). The Basics of Elearning: An Excerpt from Handbook of Human Factors in Web Design. 2005(8), pp. 2. Retrieved on 6 Nov 2006 from http://www.elearnmag.org/subpage.cfm?section=tutorials&article=20-1.

Raymond, D. et al. (2005). A Model for Content and Communication Management in Synchronous Learning. Education Technology and Society, 8(3), pp. 187-205.

Sanders, D. W. and Morrison-Shetlar, A.I. (2001). Student Attitudes Toward Web-enhanced Instruction in an Introductory Biology Course. Journal of Research on Computing in Education 33(3), pp. 251-262.

Sheard, J., Macdonald, I. and Hagan, D. (1997). Monitoring and Evaluating a Redesigned First Year Programming Course. Proceedings of the 2nd Conference on Integrating Technology into computer science education, Uppsala, Sweden pp. 37 - 39.

Tanaka, Y. (2005). Invited Workshop on Dissemination of Elearning Technologies and Applications: Memetic Approach to the Dissemination of Elearning Objects Proceedings of the 4th International symposium on Information and Communication Technologies WISICT '05, Dublin: Trinity College.

Werry, C. (2002). The Rhetoric of Commercial Online Education. Radical Teacher, Spring (63) 7.
Yang, Z. & Liu, Q. (2004). Research and Development of Web-based Virtual Online Classroom. Computers & Education, 48(2) pp. 171-184.