Next generation computer assisted assessment software: The design and implementation of WebMCQ

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Abstract

Web-based assessment allows great flexibility in the presentation of computer assisted assessment (CAA), particularly in terms of time, place and pace. For this reason, existing Web-based assessment systems can be expected to be of growing importance in education. However, the next generation of CAA systems will involve the development of software that runs entirely within the Web browser, as is currently exemplified by Web-based email. These systems will allow for the creation, delivery and monitoring of all aspects of educational assessment over the Web, and will bring with them a range of advantages in terms of ease of use, ease of edit and efficiency.

WebMCQ was developed to utilize the potential of next generation software. Users (both students and teachers) require no special software or hardware apart from an Internet-accessible computer and Web browser. It includes a wide range of features to allow for innovative educational methods in CAA, such as: practice questions for revision and exam preparation; teaching modules based on interactive questions; workgroups which allow students to create their own questions and feedback; and a range of security options for examinations. In addition, all system materials are provided over the Internet (including manuals, advice, email support and the software itself).

WebMCQ has been used in a range of contexts in Australasia, particularly in a large introductory psychology program (1400+ students). Student evaluations of the system were very positive, with 61% rating WebMCQ as "(1) Excellent" as a learning resource (on a seven point scale). Qualitative evaluations emphasized the importance of immediate feedback, the value of flexible use of CAA in time, place and pace, and the importance of the provision of practice questions with multiple layers of feedback prior to exams.

Introduction: The Rise of Web-based Assessment

Computer assisted assessment (CAA) has played an important role in education during the late twentieth century. Implementations of CAA have included self-contained software testing packages (such as those distributed by some publishers), CAA authoring systems, and CAA modules within multimedia teaching systems. In addition, optical character recognition (OCR) has been useful for the marking of multiple choice tests and exams for large courses. CAA has been used in a broad range of educational environments (secondary and tertiary education, vocational education and training, and professional and corporate training) across an even broader range of discipline areas.

Probably the greatest advantage of CAA is automatic objective marking. Computer marking (either directly or via OCR) has the potential to greatly reduce staff marking time, and has additional benefits in terms of administrative efficiency and accuracy. Particularly in the context of large courses, the benefits of automatic marking using CAA may be considerable (Dalziel & Gazzard, 1999a). While multiple choice questions (one of the most commonly used CAA formats) are not appropriate for all types of educational testing (Haladyna, 1997), and can result in some undesirable effects on student learning in certain contexts, the advantages presented by CAA are likely to see this method remain prominent among the arsenal of potential assessment procedures adopted by teachers and trainers.

However, “stand alone” CAA programs have a number of important disadvantages: the location in which these may be used is often limited to the teaching laboratories of the particular educational context; they are often limited to a specific computer platform; they require individual installation and upkeep; they are not always easy to use or easy to edit; and they are often difficult to integrate with other teaching materials (unless they have been specifically designed for this purpose, such as in multimedia CD-ROM training packages). In addition, it has been rare for CAA systems to include student evaluation within the CAA system itself, despite the importance of regular evaluation for quality control and improvement (this has been acknowledged in both Australia - Alexander, McKenzie & Geissinger, 1998, and the U.K. - Ducker, 1998). These problems may have limited the adoption of CAA despite its other advantages.

Some of these problems can be solved as a result of the revolutionary impact of the Internet and the World Wide Web (Web) on computing. The role of the Web in education has been growing at an extraordinary rate in the past five years. In the Australian context, it is now likely that most current students would have contact with the Internet or Web at some stage of their degrees, and this trend seems set to continue. Indeed, it is likely that at least some use of the Web will have become a “given” in the education of students within the next five to ten years (more than half of my first year psychology students have this attitude already!).

The Web will change many aspects of education (and society), but Web-based assessment is one of the most promising innovations in education and training. The flexibility in time, place and pace that Web-based assessment can afford for practice questions and other formative assessment methods is a major advance over previous CAA methods. In addition, the intuitive nature of the Web and its platform independence give it special advantages over “stand alone” CAA. Further, it is possible to design Web-based assessment systems which require no software installation or downloading, nor the use of any special plugins, so that using Web-based assessment becomes as simple as using a Web browser.

While there will be some particular contexts where “stand alone” CAA will remain useful (e.g., Heard & Chapman), it is likely that Web-based assessment will supersede previous systems in many contexts, in addition to fostering growth in areas not currently using CAA. Web-based assessment software can be expected to develop to include a wide range of question formats, greater flexibility in presentation of assessment material, and more advanced tracking of student usage. In many ways Web-based assessment will be the natural evolution of previous developments in CAA. However, the rise of the Web also presents the possibility of entirely new software development models, and these may be applied to Web-based assessment. Next generation software (Gazzard & Dalziel, 1998) represents a qualitative jump in the development and provision of future software systems.

Next Generation Software

We are currently witnessing the development of a new breed of software systems which run entirely over the Web. Web-based email (such as “Hotmail”) was the first of these to have a major impact on society, although there are now a range of systems offering entirely Web-based tools such as calendars, notepads and share trading. The importance of these tools is that they are independent of the operating system of the computer (and are hence truly platform independent), and thus require no software installation. They have generally been easy to use, and because they require no downloading, installation or maintenance on the user (or “client”) side, they eliminate a raft of problems associated with traditional computer software, such as incompatibilities, and maintenance and service costs.

Next generation software systems have a number of advantages over traditional software that may not be immediately obvious (Gazzard & Dalziel, 1998). Easy of use, platform independence and lack of installation and maintenance problems are all fairly clear advantages, but the additional efficiencies that arise from a centralized server approach to software are considerable. The speed of software development is increased dramatically, and software additions, changes and bug fixes can all be implemented much more easily when the software resides on a central server (rather than on many independent individual computers). Also,

software developers and users may work together more collaboratively, as users can suggest changes or upgrades which (if possible) can be implemented directly to the server, resulting in users getting faster improvements in software (rather than waiting for major releases often one to two years apart). In many cases the software development cycle can be reduced from years to months or even weeks.

Ironically, this new breed of software shares some similarities with the more traditional client/server models that existed before the rise of the desktop PC (indeed it will be interesting to see if in the future we will look back at the rise of non-networked desktop PCs in the late 80s and early 90s as an unfortunate blind alley in the evolution of human-computer interaction). Two key differences between Web-based software and past client/server approaches are ease of use (especially as a result of graphical user interfaces) and the universality of the Internet. The implementation of a standard programming language across the Web (Java) has also been important in the development of current systems. The concept of Web-based software seems set to play a major role in the future of computing.

CAA and Next Generation Software: The Design of WebMCQ

Web-based assessment is amenable to next generation software. “WebMCQ” is a system designed by the authors, based on work conducted at the University of Sydney, which implements an entirely Web-based assessment system from the point of view of both student and teacher (Dalziel & Gazzard, 1998). All aspects of not only the use of assessment material by students, but also the creation, monitoring and analysis of assessment material by teachers is conducted via the Web. The system requires no software installation, nor any special Web browser plugins, and hence takes maximum advantage of the benefits of next generation software. In addition, the system is “degradable”, in the sense that where students are using early Web browsers (down to Netscape 1.1 or Internet Explorer 2.0), the system will readjust the presentation of material to ensure equivalent user experiences across different environments. Due to the need for Java within the teacher side of the system, it will only run on Java enabled browsers (Netscape 3.0 and above, Internet Explorer 4.0 and above), although this does not present a significant usability problem, as it is easier to assist a small number of teachers to have the appropriate operating environment than it is to expect a large number of students using the Web from a very wide variety of backgrounds to have the latest Web browsers and/or special plugins.

From the student’s point of view, WebMCQ can be used for summative assessment (in which feedback is only provided at completion) or for formative assessment (where feedback can be ongoing). To encourage learning during formative assessment, a multi-layered feedback system was incorporated to allow students to navigate through material according to their level of understanding (see Figure 1). In addition, a number of configuration options were

provided to students to allow for different learning styles when using WebMCQ for formative assessment, including the ability to have randomly selected questions presented from a question bank, allowing feedback to be withheld until the student wishes to see it, and the ability to create artificial time limits. These options may be enabled or disabled by teachers according to the intended use of the CAA material (for example, these configuration options would not normally be appropriate for a formal exam). In the case of exams, a variety of security measures (including multiple password protection systems, IP address limitations, SSL and other methods) are available to ensure secure transmission and storage of information. For demonstrations of the WebMCQ system from the student point of view, visit http://www.webmcq.com/ and follow the link to the demonstration page.

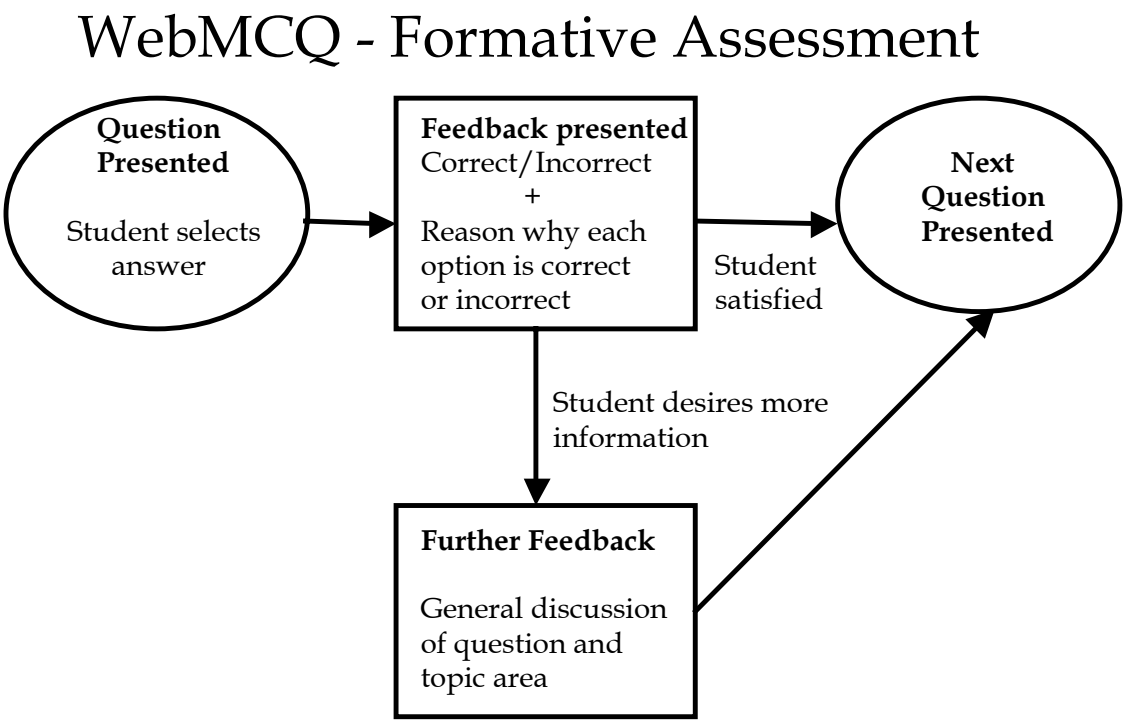

Figure 1: Structure of the question and feedback system used in WebMCQ.

The benefits of next generation software are most obvious from the teacher's point of view, as all aspects of dealing with assessment material are handled via the Web browser. Teachers are given access to a secure password protected account on the relevant server in which a range of tasks can be performed, such as: questions can be created, edited and uploaded; usage restrictions and options may be set; and monitoring and analysis of student performance can be conducted and downloaded. In addition, a standard evaluation survey may be presented to students at the conclusion of assessment material, and student responses are collated for teachers within the "evaluation" section of the account. This focus on evaluation is important for the revision and development

of future material, and it can also provide a guide to the strengths and weaknesses of the current deployment of CAA. For a demonstration of the teacher side of the system, visit the demonstration page at http://www.webmcq.com/ and follow the instructions at the bottom of the page to access a “guest” account.

Ease of use, ease of edit and the ability to customize the way assessment material is used are among the most important features of the teacher side of the system. WebMCQ was designed so that basic familiarity with word processing and Web browsing would be sufficient to create and edit assessment material without additional training. Like many next generation software systems, there is no special programming language to learn, nor are complex sets of non-intuitive commands needed. A variety of customization options allow teachers to structure the way the assessment material will be used, and to control the amount of flexibility students have in adapting the material to their preferred learning style (this is generally more relevant for formative assessment, as summative assessment typically requires stricter formats).

The concept of next generation software has been developed even further in the case of WebMCQ with a “software as service” model (Dalziel & Gazzard, 1999a). Rather than providing WebMCQ as a “disk in a box”, where all the tasks of installation, maintenance and setting up a Website are incumbent upon the user, these tasks are provided as part of a service. This approach allows for greater efficiency in the management of the system by those most familiar with it. It also allows changes, upgrades and bug fixes to be implemented far more readily than with traditional software. The service provides email support to users, and a range of materials available for downloading from the WebMCQ Website. As a result of this service approach to software, which is based on yearly licence fees, initial startup costs (both directly and indirectly in terms of technical staff setup time) are greatly reduced, and new accounts can usually be made available for use within one or two days from the date of request. Where a large number of WebMCQ licences are required for an institution, an “on-site” server licence may be appropriate, in which case all aspects of installing and maintaining the system are done remotely, again removing the technical burdens from individual teachers.

It is important to realize that while much of the above discussion of WebMCQ is specific to the business model of the company involved, this model is part of a much wider movement in the nature and use of software that is likely to have a substantial effect on future educational software developments. For this reason, it may act as a guide for other systems, and it indicates a variety of ways in which the quality and efficiency of CAA can be improved by adoption of innovative approaches to software development and delivery. It also demonstrates a shift within university educational software more generally from attempting to create and maintain software systems internally, to acquiring external systems which may be adapted to the needs of the institution (a similar

shift is currently occurring in the use of Enterprise Resource Planning, or “ERP” systems in universities for financial and human resources management, Pahlman, 1999). This shift involves a move away from viewing universities as software developers, and towards seeing universities as content providers (using commercial systems as a platform for content). In many ways this may be an appropriate evolution of the use of new technologies in teaching and learning, as ultimately few universities will be able to maintain the investment in ongoing development of software needed to keep pace with commercial development (Vitale, 1999).

The Implementation of WebMCQ

WebMCQ’s development began in 1997 when an initial “one off” formative assessment quiz was developed for First Year Psychology at the University of Sydney. As a result of high levels of student usage (over 90%), and very positive evaluations, a redevelopment of the system during late 1997 and early 1998 resulted in a generic Web-based multiple choice assessment system that could be used in any discipline area (Dalziel & Gazzard, 1998). At the same time, a range of security features were implemented for formal exam testing, and development of a Web-based teacher interface was initiated. The new system was used for both formative and summative assessment with the same First Year Psychology course at the end of first semester 1998 (May/June), with similarly high levels of student usage and positive evaluations. As a result, WebMCQ was commercialized during late 1998 as an independent company offering WebMCQ as a service (as described above). As of April 1999, it has over 60 licensees in three countries, and is being used by a number of universities, corporations and other educational organizations. WebMCQ is being used in a wide range of discipline areas, such as psychology, biology, physics, computing, geology, pharmacy and veterinary science, as well as in distance education and university preparation courses.

The original implementation of WebMCQ in First Year Psychology was based on practice questions prior to an end of semester tutorial test (30 minutes). Due to the large number of students in the course (over 1400), formative assessment which was computer marked was a useful tool for aiding student learning without excessively increasing staff marking loads. Students were given approximately ten practice questions on each of their eight main topic areas for the tutorial test, and they were informed that a few of these practice questions may be included in the formal tutorial test. Formative material was release a few weeks prior to the tutorial test, and computer labs were made available for a full week for students to practice prior to the test. Due to the Web-based nature of the material, students could also choose to access questions from elsewhere on the university campus, or from home, work, etc (over a third of students accessed material from outside the university).

All practice questions were designed with two layers of feedback - the first layer was specific to the question asked, and typically explained why certain answers were incorrect (or correct), whereas the second layer of feedback was more general, discussing the topic on which the question was based, and referring to other resources (student handbooks, textbooks and Web-based tutorials). This feedback structure (see Figure 1) allowed students to navigate through the material according to their own level of understanding. Graphics were included in some questions to aid testing or understanding where appropriate. Following the practice questions, the formal test was run in class also using WebMCQ (although students who were not confident to complete the test on computer were allowed to request a paper version of the test - approximately 40 students chose this option). At the completion of the formal test, students received their mark immediately, and these were then collated by WebMCQ for all students.

Student evaluations of the system were very positive (Dalziel & Gazzard, 1998). Regarding the formative assessment material, an evaluation question asked students to rate WebMCQ as a learning resource (on a seven point scale): 61% of students rated WebMCQ as "(1) Excellent"; 28% rated it as "(2) Very Good"; 9% rated it as "(3) Good"; and 2% rated it as "(4) Average". No negative responses (5, 6 or 7) were received. Qualitative feedback indicated that the most popular aspects of WebMCQ were related to "explanation of wrong answers" and "immediate feedback on answers". Other positive comments included:

> "Very informative and thorough"
> "Great having it on the Internet"
> "It emphasizes your strengths and weaknesses"
> "Easy to use, a fantastic learning tool"

An additional theme among student comments was that using WebMCQ had encouraged them to go back to their class notes and do further study, such as:

> "It motivated me to study, since I knew less than I thought I did"

More general comments about the system were overwhelmingly positive:

> "It gave me a chance to get a perspective on what to study, as well as being an opportunity to test my knowledge"
> "It was comprehensive, and very helpful having the 'more information' option and the summaries"
> "The 'more information' section [was best], as it helps students to remember the tutorial, and to put questions in context, giving students the opportunity to take notes"

Since these initial evaluations, similar positive results have been obtained for subsequent use of WebMCQ in First Year Psychology and in other contexts (e.g., O'Byrne, 1999). Of particular interest are the qualitative responses to an

implementation of WebMCQ for a second year level course in which no feedback was provided other than whether the answer was right or wrong (Dalziel & Gazzard, 1999a). Student evaluations of this more limited implementation of WebMCQ were still positive, with a special emphasis on the way that practice questions help students prepare for formal exam questions (see particularly the third quote):

> "Answering questions about the whole course gave me an idea of what areas need more revision. Thank you for this opportunity."
> "[WebMCQ] relieves the pre-exam tensions, and shows whether or not your have done enough study."
> "The questions seemed to be worded different to how we've been taught throughout the year. In the exam the different wording always seems to throw me, I think this practice quiz helped me gain much needed confidence and a chance to think about all the stuff I've learnt in a different way."
> "Easy to use, gave indication of exam layout, helped enormously - should be a part of all options."

In terms of cost savings and efficiency, in the case of First Year Psychology, the total cost for marking all 30 minute tutorial tests prior to the implementation of WebMCQ was approximately $3,000 per semester ($6,000/year). The cost of a WebMCQ license for an Australian educational course in 1998 with over 500 students was $500, plus a once-off setup cost of $100. Given these figures, the cost of WebMCQ was a tenth of the original marking costs, representing a substantial saving on past practices. Further analyses of WebMCQ efficiencies (especially in terms of "total cost of ownership") are currently being conducted.

Ongoing Development of WebMCQ

While the initial emphasis of WebMCQ was Web-based multiple choice questions (hence the name of the system) for formative and summative assessment, subsequent developments have broadened its potential uses. While multiple choice questions have sometimes received criticism for their role within education, these criticism are frequently based on a narrow view of the potential of this format (Dalziel & Gazzard, 1999b). Innovations such as the use of multiple levels of feedback, "information pages" which can discuss issues without using questions, short answer questions, and the development of interactive training modules are all developments beyond simple multiple choice items which expand the educational uses of CAA. In particular, multiple choice questions with layered feedback can provide a framework for entire teaching modules, in which questions may be used to prompt consideration of issues or challenge existing beliefs. When this is integrated with feedback which explains new ideas and builds on existing learning, multiple choice questions can be a structure for whole multimedia teaching packages. Given the ease of editing

material within WebMCQ, there is much to recommend this approach over more traditional multimedia authoring tools.

In the case of formative assessment, in which students may wish to use the material over several sessions (potentially from different locations), a password system allows them to continue past work without restarting from the beginning. This system also allows students to enter an email address so that results can be forwarded to them directly at the completion of a test. A further recent development is the introduction of “student workgroups”, where students may be provided with access to a limited section of the teacher’s interface so that they may create their own questions and feedback. This approach radically inverts the traditional concepts of CAA, in which students themselves may learn form the experience of trying to formulate questions and considering the responses of their peers (Dalziel & Gazzard, 1999b). Student creation of questions generally requires a high level of understanding of content, as well as creativity, and hence transcends the normal educational boundaries (and criticisms) of CAA. The use of next generation software principles makes this concept of CAA possible due to all tools being entirely Web-based. Evaluations of this approach are currently being conducted.

Finally, “Version 2” of WebMCQ is currently under development, for release during 2000/2001. This will be a greatly expanded system for Web-based teaching and learning, and will include not only a broader range of assessment options, but may also include other useful course management features such as noticeboards, discussion groups, chat rooms and so on.

Summary

This paper has argued that Web-based assessment is the natural evolution of many previous computer-based systems. It is likely that Web-based assessment will become a regular component of many university courses within the next five to ten years. During the same period, the revolution in software development and delivery, here described as “next generation software”, will continue to be highly influential on computing, especially in relation to the Web. WebMCQ is a system designed to take advantage of the principles of next generation software in order to benefit the creation, delivery and monitoring of educational assessment material. All aspects of both student and teacher use of CAA may be run from within the Web browser, and this greatly enhances ease of use, ease of edit and efficiency. Student evaluations of this approach to CAA are very positive, with qualitative evaluations emphasizing the importance of immediate feedback, the value of flexible use of CAA in time, place and pace, and the importance of the provision of practice questions with multiple layers of feedback prior to exams.

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