Learning Diagnostic Imaging: the use of ICT in an image-based Distance Education subject

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Abstract This paper reports ongoing development research into ways that ICT can be used to enhance distance education materials in image-based subjects. The work has been focussed around a unit of study called Veterinary Diagnostic Imaging, where Master's students learn to acquire, read and make diagnoses from radiographs and ultrasound images.

ICT was used in five ways in this work: digital interactive images in QTVR format; interactive self-tests implemented in Microsoft Word; submission of assignments through WebCT; asynchronous discussion of problems using WebCT; and a synchronous electronic whiteboard developed using the Macromedia Shockwave multi-user server.

A plan was developed to formatively evaluate each tool, and determine its usability and potential improvements. In the body of the paper, each tool is described, and evaluation evidence is discussed. Overall, the use of ICT was found to be effective for students. However, there is still scope for a number of improvements.

Introduction

For several years now, we have been working on using Information and Communications Technology (ICT) to make enhancements to a unit of study, Veterinary Diagnostic Imaging (V620), offered by Murdoch University as part of a Master of Veterinary Studies. This advanced coursework degree is available within Australia and internationally through distance education, and targeted at professional veterinarians in practice. The aim of the unit is to assist students to acquire, read and make diagnoses from radiographs and ultrasound images.

Veterinary Diagnostic Imaging covers theoretical material in radiographic technique and ultrasound principles, and the imaging and interpretation of various anatomical regions in small animals. Students are presented with a large number of case studies, and work on their own to evaluate, recognise normal and abnormal structures, to define the patterns of change present in disease processes, and to make diagnoses from these.

The case studies are carefully designed to scaffold (Palincsar and Brown, 1984) students' learning. Initial case studies provide questions and hints to assist students in their diagnoses. Support is progressively removed as students progress through each section, until later examples are structured as if for an expert. Students practice on the majority of case studies, before formal assessment on the final two or three case studies in each section of the subject.

It is difficult for students to learn a practical and visual subject, such as this one, solely through print-based distance education. Diagnostic imaging is taught in a face-to-face mode by observing an image or images on a viewbox, measuring appropriate characteristics and discussing observed features and abnormalities. Discussion is typically accompanied by pointing and other gestures. This interaction between teacher and student is difficult to achieve in the absence of face-to-face contact.

We have been working since 1999 to use ICT to alleviate some of these problems. Our initial work focussed on providing radiographs and ultrasound images to students on CD in Apple's QuickTime Virtual Reality (QTVR) format (Phillips, Pospisil, and Richardson, 2001). QTVR enabled file sizes to be kept small, and enabled students to zoom in and pan around on the images with minimal loss of diagnostic clarity. It also enabled hotspots to be overlaid on the images, to draw students' attention to areas of interest.

In a second round of development, the focus was on providing better feedback to students, through interactive self-tests, simplifying submission of assignments and providing an asynchronous discussion forum. At the same time, an electronic whiteboard was being designed to enable students and staff to synchronously view, annotate and discuss radiographs.

There are, therefore, five elements to the ICT enhancement of this unit of study:

- Digital interactive images
- Interactive self-tests
- Submission of assignments
- Asynchronous discussion of problems
- Electronic whiteboard

The next section briefly outlines the formative evaluation approach taken. The body of the paper describes the development of the five tools, and the evaluation results which directed their ongoing improvement.

Evaluation Plan

The evaluation framework proposed in the ASCILITE Evaluation Handbook (Phillips, Bain, McNaught, Rice, and Tripp, 2000), derived from (Bain, 1999), was used to assist the design of the evaluation plan. In particular, the evaluation focussed on two aspects of the framework:

- formative monitoring of the learning *environment* (to determine whether the tools were functional in their context and accessible/attractive to students)
- formative monitoring of the learning *process* (to determine whether the innovations were influencing the learning process as intended)

A number of sources of data were used to evaluate the usability and effectiveness of the various parts of this development. These included design specifications, expert feedback, student observation, lecturer feedback, online usage statistics and an email survey of student experiences.

The 22 students were sent an email message seeking free-form comments about their experiences with the unit as a whole, and, specifically, with the ICT innovations included in the unit. We wanted to find out how students used the tools, and how the tools could be improved. The questions were designed specifically to elicit descriptive and deep responses from the students. Ten of the 22 students responded to the survey.

Digital Interactive Images

Radiographs and ultrasound images were presented to students on CD in Apple's QTVR (Apple, 2000) format when the ICT-enhanced unit was run for the first time, in 2000. Students also received the majority of images in hard-copy format. Previous work (Phillips et al., 2001) indicated that students found the CD considerably more convenient than the bulky hard-copy radiographs. The CD images were most useful for gross detail and for study purposes. The image hotspots, zooming and panning facilities were also found to be valuable features.

However, a significant number of students had technical difficulties with the CD. Furthermore, students found that the image quality was insufficient for them to identify areas of fine detail on radiographs, and they preferred to use the manual techniques they were used to.

The feedback from students indicated that they would like to receive images in both modes. The CD images were found to be suitable for study purposes, because of their convenience and flexibility, but students wanted hardcopies for the assignments, because of a perceived higher image quality.

The unit was presented again in 2002. The user interface was completely revised, based on earlier feedback. Also, detailed documentation was provided to students about how to install the QuickTime plug-in, and how to use the software.

In 2000, images were digitised using an obsolete x-ray film digitiser (Rayvision 320) with a maximum resolution of only 146 dots per inch and a low optical density range. It was thought that this was the cause of the low image quality reported by the lecturer and students for some radiographs. For 2002, almost all of the images were re-scanned at higher resolution and optical density range with a recent model x-ray film digitiser (Cobrascan). Students were still provided with both digital and hard copy radiographs for worked examples and assignments (approximately 50% of the images).

Evaluation Results

The students who completed the email survey in 2002 were largely very positive about the CD of QTVR images. As before, they appreciated the convenience and flexibility of the CD images.

There were very few technical problems in 2002, and, although a substantial number of students expressed doubts about their IT literacy, all except one were able to use the CD images effectively. "*I found the CD's very user friendly*". The documentation provided on the CD was found to be very helpful by most students.

Hotspots were found to be especially valuable by most students. "I found the hotspots really helpful because I'm not very good at visualising descriptions and often get the wrong impression of what's trying to be relayed to me by words alone." However, because of time constraints, hotspots were only inserted on the first batch of images. There was strong demand from students surveyed for hotspots to be more widely available.

While some students were enthusiastic about the CDs, again most students found that the image quality of the hard copies was superior. One student found the quality of the digital images "really frustrating", two students predominantly used the CDs, but the majority used both methods, with a preference for the hard copies for assignments.

Image quality was an issue that we had attempted to address in the second round of development. Radiographs had been scanned at higher resolution, with improved equipment, but students (and the lecturer) still found them to be inferior to the hard copies. The discrepancy seems to arise from the capabilities of the video hardware and monitor used. When a high quality, calibrated monitor is used, fine details are observable. However, we had no control over the hardware used by students. This issue needs further exploration.

The available screen area was an issue for some students in some cases, where multiple images needed to be observed at the same time. However, the more technically-adept students were able to surmount these problems.

Some students found that it took as long, or longer, to bring up the images on the computer as it did to pull hard copies out of folders. The user interface and response times need to be considered in the next version.

Several students discovered, belatedly, that it was beneficial for them to investigate both CD images and hard copy radiographs, because different features are visible on each in some cases. In some cases, there are artefacts on the film copies of radiographs sent to students that are not present on the CD images.

In summary, the speed of access and usability of the digital images needs to be refined; the effects of monitor quality and resolution need to be investigated; and students should be advised to use both sources of images in future.

Interactive Self-tests

After a thorough feasibility study (Phillips, 2002), interactive self-test case studies were implemented in Microsoft Word using the built in macro language. Microsoft Word has the following factors in its favour:

- students are likely to be familiar with it;
- students are required to type answers, and a word processor application such as Word is custom-designed for this purpose;
- incomplete answers can be saved until the student can come back to them;
- existing materials are already in Word format;
- the lecturer can readily create new case studies;
- hyperlinks can be created to launch images in the QuickTime Player application, so that images can be compared and resized at will.

Each self-test document is created from a Word template, into which questions can be entered. A special Administration menu enables staff to insert text boxes into which students can type answers. The Administration menu allows staff to enter feedback text (containing ideal answers) for each question, and to insert submit buttons. The feedback text is formatted as *hidden text* identified by a *bookmark*. When the submit button is pressed, the bookmark is selected and the answer text is made visible. This is shown in a simple example in Fig. 1.

The nature of the case studies required students to view varying numbers of images of varying sizes and shapes together with the case study text. One advantage of the Word solution was its integration with the MacOS and Windows operating systems, which allow students to arrange images and text on screen to suit their needs.

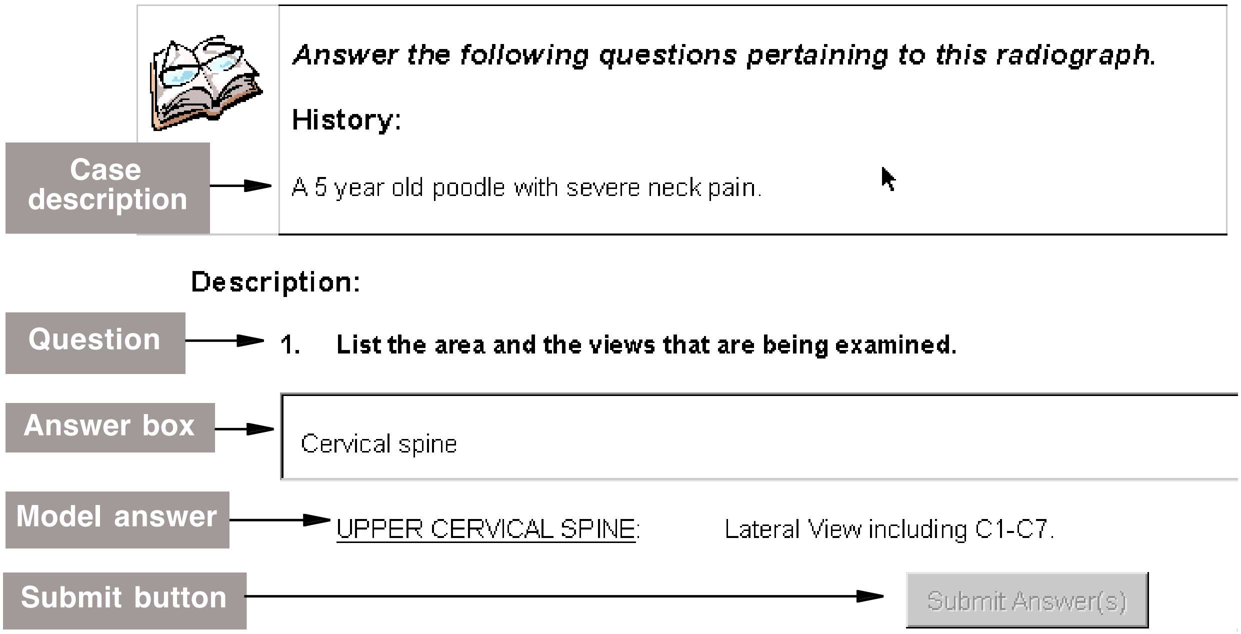

Figure 1. A simple example fragment of the self-assessment functionality provided through Microsoft Word.

A second advantage was that radiography staff could create new self-tests without needing any special programming skills.

The version of the self-tests provided to students in 2002, and shown in Fig. 1, used ActiveX (Microsoft, 2002a) controls in conjunction with the Visual Basic for Applications macro language (Microsoft, 2002b). ActiveX was needed to embed the Submit button in the Word document. A drawback of this design decision was that the self-test macros only functioned with Word for Windows 2000. The interactive parts did not work with other versions of Word or on other platforms.

Evaluation Results

Of the ten students who responded to the email survey, only four used the interactive self-tests, and only one person preferred to use them. One student reported having the wrong version of Word, and another cited lack of time as the reason. Other students did not realise that the interactive self-tests existed, or could not find them on the CD. Others preferred to work in a way with which they were familiar — on paper.

A group of students, who attempted to use the interactive self-tests, found them too cumbersome and slow. Students had trouble finding the right files to open, and experienced difficulty in arranging the document and associated images on screen. This feedback, combined with evidence from observations of undergraduate students using the interactive self-tests on campus, indicated problems in the highest level user interface on the CD.

Due to deadline pressures, the index of Word documents was stored in one folder, and the index of radiograph images was stored in a second folder. There was no cross-referencing between these folders, and students had to open each independently, and navigate them separately. This is a relatively easy interface issue to resolve.

A second interface improvement already identified is to insert thumbnails of relevant images formatted as *hyperlinks* within each Word document. Clicking on these thumbnail images then loads the appropriate larger image in the QuickTime player.

A further revision of the software has already been implemented, by removing the dependence on ActiveX controls. In the latest version, the 'submit' buttons are presented as items in a floating, custom toolbar. This enhancement enables the interactive self-tests to function on both Windows and Macintosh computers, with Word versions 97, 2000 and X.

The instructions and documentation given to students also needs to be reviewed, because it is a concern that some students did not know about the existence of the interactive self-tests. Given the enthusiasm of the students for the QTVR images, it would be expected that students would also adopt the self-tests.

On the other hand, attempting to arrange a Word document and several large images on a limited screen area may be an insurmountable problem. The interactive self-test technique may be more applicable to a non-pictorial subject, or one with smaller images.

Assignments

After students have worked on a section of the course, they complete assignments in the form of formally-assessed case studies. Word documents are also used for the assignments, but without the extra self-test functionality. Students are expected to copy the template document from the CD-ROM to their hard disk, type their answers to the assignment questions directly into the document, and save it.

A serious problem with assessment in external studies is the delay in students receiving feedback on assignments sent by post (Mason, 1995, p208). This may take 7-10 days, in addition to tutor marking time. We attempted to minimise this delay using ICT.

The unit of study has an associated web site available through the WebCT Learning Management System (WebCT, 2002). Completed assignments are uploaded for marking through the WebCT Assignment Submission Tool. Once an assignment is uploaded to the WebCT course and checked by staff, an ideal answer is made available to the student so that he or she gets rapid feedback on their work. The WebCT selective release function was used, based on a special field for each assignment in the student database, to make the feedback visible to students. Subsequently, after the assignment has been marked, the students formally receive online feedback on their individual work.

Evaluation Results

Feedback from the email survey indicated that students had few difficulties in submitting their assignments in this way. Some were nervous beforehand, but found the process easy to use. Students particularly appreciated the extra time it gave them to complete their assignments, without having to factor in postal time. They also appreciated the answer templates on the CD. Students generally appreciated the speedy availability of the model answers, although several complained about the time it took to receive specific feedback on their work.

While students found the assignment submission process efficient, this was not the case for the lecturer. She found it cumbersome to download student work from WebCT, and then found it difficult to distinguish which file belonged to each student, because no filenaming convention was in place.

It also took her significantly longer to mark and annotate assignments directly in Word, than it had previously done on paper. These factors led to delays in returning assignments to students.

Discussion Forum

In earlier versions of the unit, one of the major frustrations experienced by lecturing staff was in communicating with students about problems in interpreting images. When students had problems with particular images, often the only option open to them was to telephone their tutor. However, with ultrasound and radiograph images, it is often difficult to describe exactly which diffuse area of grey one should look at. Often, many minutes would be spent in conversation, before it was realised that the discussion was about different areas of the image. In a face-to-face situation, on the other hand, a simple pointing gesture would resolve this issue in seconds.

When WebCT was adopted as a means of submitting assignments, extra tools were available for communication between students and between students and teacher. The WebCT asynchronous discussion forum was used for broadcast information about the conduct of the unit. It was also used as an optional means for students to discuss problems, although it was recognised that this would be inferior to a face-to-face situation.

Evaluation Results

The email survey indicated that usage of the WebCT discussion forum was mixed. Two students stated that they did not use it. Other students found the forum not useful for discussing images: "*[I] found discussing images over the internet quite useless as I would want to point to an area and ask questions re the interpretation of shade/pattern etc.*".

Some students reported, however, that they appreciated the opportunity to ask questions about unit work. Others took advantage of the WebCT discussion forums to overcome the loneliness of distance education: "*[It was] good to have discussions and contact with fellow students. My biggest problem was just plain old loneliness*".

Inspection of the usage logs recorded by WebCT revealed a different picture. One student did not access the WebCT site at all. The remaining 21 averaged 187 hits on the site, read 112 forum articles and posted an average of 4.5 articles each. Only 11 students posted articles, but students who simply "lurked" read almost as many articles as those who contributed actively to the discussion. Eight students returned to the WebCT site months after the end of the unit.

Some technically adept students overcame the limitation of describing problems in text by capturing screen dumps of images, annotating them, and attaching them to forum messages for discussion. This approach taxed the technical skills of the lecturer, who was not able to respond in a visual fashion to the students.

Whiteboard

At best, the WebCT discussion was a poor substitute for face-to-face discussion around a view box. A better means was required to simulate the face-to-face situation. As one student in the email survey wrote "*The worst aspect [of the unit] is no direct interaction*".

The technical problem facing us was how to simulate the face-to-face situation with QTVR images. Electronic whiteboard solutions exist in the market place, but these typically involve static images. In our case, we wanted to be able to use QTVR features, such as panning and zooming, while at the same time being able to annotate key areas on the image.

A second reason that commercial solutions could not be used arose from observation of expert radiologists. The experts not only highlighted areas, but also measured angles and distances between features. These tools used in clinical practice were not available in commercial products.

A specification was, therefore, developed for an electronic whiteboard application which would share QTVR images over the web, and facilitate communication between students and teachers about specific features of an image. Both parties needed to:

- view the same image on screen at the same time, and zoom and pan within the image;
- highlight areas of interest, and annotate the features;
- note angles, distances, etc., using tools common in clinical practice;
- choose another image to view;
- type comments to each other.

The solution we chose was provided by MacroMedia's ShockWave Multi-user Server. This is an application which enables ShockWave movies on the web to communicate with each other. The Multi-user server comes bundled with the commercial version of MacroMedia Director. Code for an electronic whiteboard was embedded as a 'behaviour' within Director, and we modified this to work with QTVR.

A screen capture of the whiteboard is shown in Fig. 2. Users who have logged in are shown in a speaking list at the top left. Each user is assigned a unique colour, and annotations created by a user are drawn in that colour. The speaking list is divided into three sections. The top section contains the name of the user who currently has the whiteboard marker. The middle section contains the names of the people who have requested the whiteboard marker, and the bottom section contains the names of other people.

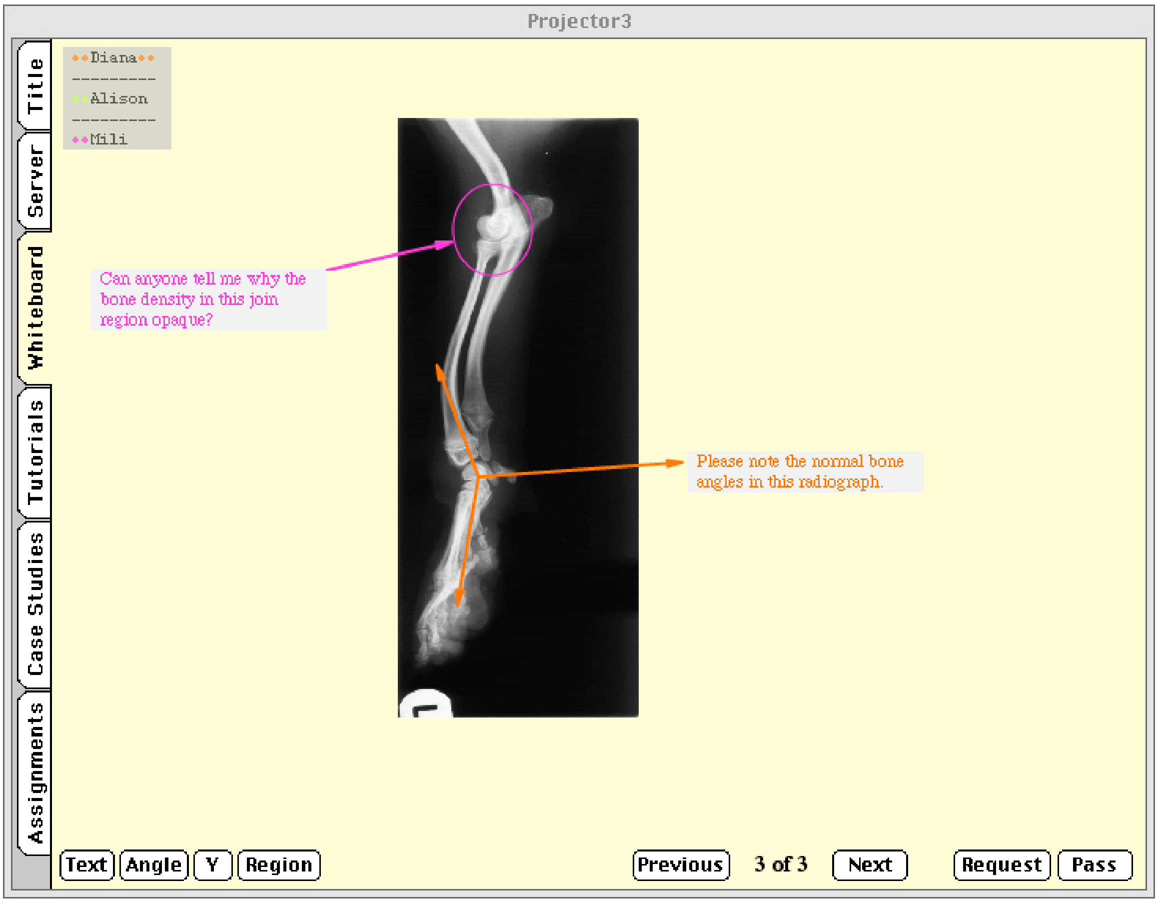

Figure 2. Electronic whiteboard screen capture.

When a user has the whiteboard marker, they have the exclusive right to create and edit annotations, and alter images. The user with the whiteboard marker can relinquish control of the marker by clicking the Pass button (bottom right). The user who was at the top of the request queue receives the marker. Users can use the Request button to request control of the whiteboard marker. The tools are available at the bottom left, and some examples of their use are overlaid on the radiograph.

As the whiteboard software was developed, it became clear that activity on the whiteboard could be recorded. Each time a user passes on the whiteboard marker, a new frame in a movie can be recorded. Because all the tools are implemented as vector objects, the data required for each frame of the movie is relatively small. With the recording feature, it is possible to roll back to previous frames and continue discussion from there.

A further advantage of the recording feature is that online discussions can be saved for future playback. In this way, students who could not attend scheduled sessions could replay the discussion later. The whiteboard could also be used individually by the lecturer to record tutorials, demonstrating how to diagnose a particular case.

Evaluation Results

The Whiteboard tool has gone through several incarnations, arising from feedback from expert users and students, and from the need to resolve technical problems. Six students worked in three pairs on computers in three neighbouring offices, and the lecturer was working from another office. An observer watched the use of each computer and noted any issues.

In the initial implementation, the chat function was in a separate window to the whiteboard, and both could not be viewed at the same time. Students found this very clumsy.

A second problem was that screen refreshes on machines of waiting users were too slow. There was no indication that another person was working on the whiteboard until the pen was passed on. To users, it appeared that the system had stopped working. Users requested an audio alert when the marker was passed on.

A third issue was that the lecturer had no mechanism to take control of the marker when necessary, and had to wait for the pen to be passed along the speaking list. There were times when the lecturer needed to intervene to keep interactions on track.

From a usability point of view, the ability to manipulate the QTVR image caused problems, because the annotations were not directly linked to the image. If a student, for example, zoomed in on a portion of the image, then the annotations were no longer useful, because they remained where they were. In subsequent versions, students navigate to the required view, and then capture a static image for annotation.

A major technical barrier was the inability of the QTVR xtra in Director to adequately control the QTVR movie. Instead, a custom image viewer had to be developed, to implement the required functionality.

Development and testing of the whiteboard is continuing.

Conclusion

Overall, the use of ICT in this unit of study has been successful. Students very happy with the conduct of the unit, and the performance of the lecturer, as testified below:

> *"I found this course fantastically good and I really appreciate the HUGE effort that you all put into putting it together."*
>
> *"I think you put a lot of effort into the materials. You are to be congratulated for undertaking a difficult task - teaching an imaging subject to remote students."*
>
> *"This has been the most useful course I have done by far. It has greatly improved my quality of practice and I use the new skills every day. Obviously a lot of time has been spent on the preparation of the course and it has been designed to be practical. I thought the structure was great and would not change it."*
>
> *"Case based learning was awesome and practical."*

However, a number of areas of improvement were also identified. The speed of access and usability of the digital images needs to be refined. The effects of monitor quality and resolution need to be investigated, and students should be advised to use both sources of images in future. Hotspots should be progressively added to the digital images.

The interactive self-test technique was not widely-used, but there is no evidence to suggest that it cannot be used in a range of subjects, especially those not requiring display of large images. The online assignment submission and discussion forum alleviated some of the drawbacks of distance education for the students.

Work is continuing on developing the electronic whiteboard, and on expanding use of the tools developed to benefit students on campus.

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References

[1] APPLE COMPUTER INC. (2000) *QTVR Home Page*. Retrieved May 6, 2003, from the World Wide Web: http://www.apple.com/quicktime/qtvr/

[2] BAIN J. (1999) Introduction to special issue on learning centred evaluation of innovation in higher education Higher Education Research and Development **18** (2) 165-172.

[3] MASON R. (1995) *Using Electronic Networking for Assessment* in F. Lockwood (Ed.), *Open and Distance Learning Today* (1st ed., 208-217). London and New York: Routledge.

[4] MICROSOFT (2002a) *How to Write and Use ActiveX Controls for Microsoft Windows CE.* Retrieved 8 March, 2002, from http://www.microsoft.com/com/wpaper/#ActiveXpapers

[5] MICROSOFT (2002b). *Visual Basic Home Page*. Retrieved 11 March, 2002, from the World Wide Web: http://msdn.microsoft.com/vba

[6] PALINCSAR A. AND BROWN A. (1984) *Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities* Cognition and Instruction **2** 117-175.

[7] PHILLIPS R., BAIN J., MCNAUGHT C., RICE M. AND TRIPP D. (2000, April 10) *Handbook for Learning-centred Evaluation of Computer-facilitated Learning Projects in Higher Education*. Committee for University Teaching and Staff Development Project. Retrieved April 9, 2002, from http://cleo.murdoch.edu.au/projects/cutsd99/handbook/handbook.htm

[8] PHILLIPS R. A. (2002) *Innovative use of Microsoft Word and QTVR for Teaching Radiology and Diagnostic Imaging* in J. Cook and D. McConnell (Eds.), *Proceedings of the 9th International Conference of the Association for Learning Technology* (pp. 71-81). Sunderland, U.K.: Association for Learning Technology. [Online] www.alt-c2002.org.uk.

[9] PHILLIPS R. A., POSPISIL R., AND RICHARDSON J. L. (2001) *The Use of a QTVR Image Database for Teaching Veterinary Radiology and Diagnostic Ultrasound to Distance Education Students* Australian Journal of Educational Technology **17** 96-114.

[10] WEBCT (2002) *WebCT: World Wide Web Course Tools.* [Online source]. Retrieved 8 March, 2002, from the World Wide Web: http://www.webct.com