Evaluation of *MRI Concepts* as a teaching and learning resource

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Introduction

The education of medical imaging (MI) students at universities includes the teaching of many imaging modalities including general x-ray, fluoroscopy, conventional angiography, digital subtraction angiography, ultrasound, computer tomography (CT) and the latest modality, magnetic resonance imaging (MRI). Ultrasound and MRI differ from the other modalities as they do not use ionising radiation, x-rays, as their means of producing an image of the patient. Ionising radiation is the focus of the teaching to MI students in the first two years of their three-year undergraduate degree. MRI, which utilises high magnetic fields and radio-waves to acquire images (Stark and Bradley, 1999), is only broached in the third year of the MI degree.

The physics and principles of MRI are vastly different from the other imaging modalities taught at undergraduate level and require additional teaching resources and approaches for student understanding. Medical imaging undergraduate students also need to evaluate magnetic resonance (MR) images to become familiar with MR contrasts of T1, T2 and Proton Density (PD). A further part of the course's requirements is the ability to evaluate MR image quality. This requires a knowledge of the MR parameters that affect both MR image contrast and quality. This evaluation of MR contrast and quality, in the past, has typically been achieved through students evaluating images in texts, and on occasions, having access to clinical MRI units. Textbooks typically used in MI courses (Hashemi and Bradley, 1997; Westbrook and Kaut, 1998; Bushong, 1996; Woodward and Freimarck, 1995) tend to provide only a few examples of MR image contrast and very few examples of how MR parameters change both MR contrast and quality. Student access to clinical MRI units is difficult to gain. Of the 130 internal and 50 distance education (DE) students at Charles Sturt University (CSU) in 1997, less than 5% have had any substantial time observing an MRI unit in operation (internal CSU survey; 1997 – unpublished).

A project was proposed to assist in overcoming the above difficulties. The project's goals were to simulate production of clinical quality MR images on a PC environment and allow students to interact with and manipulate MRI factors so as to be able to analyse the changes in the resultant MR images. MR image contrast and quality assessment would be the focus of the use of such a teaching tool. An additional benefit would be that a PC based program would provide equity between internal and DE students, where DE students often only have limited access to library resources.

Previous approaches to MRI undergraduate education

The previous teaching of undergraduate MRI physics and principles involved typical classroom approaches complemented by extensive referencing to texts. Many aspects, such as MR spin factors, T1 recovery, T2 decay, image formation and MRI instrumentation lend themselves well to such approaches. Image characteristics such as MR contrasts of T1, T2 and PD and MR image quality and the parameters that affect these characteristics do not lend themselves to classroom teaching and learning. Classroom approaches, for the teaching of these image characteristics, have been to display MR images, photocopied from texts or copies of clinical images, by overhead

projection. Such copies inherently lose quality on copying compared to the original and subtleties of image changes are easily lost.

Although no benchmarks had been established, student knowledge and understanding of MRI, and in particular, MR image contrast and quality, were being hindered by these teaching methods.

Developing a new teaching resource

A variety of authors (Cox, 1997; Dorman, 1997; Dyrli and Kinnaman, 1995) have discussed the advantages in delivery of educational material and student learning through the use of information technology (IT). Silverman (1995) proposes the purpose of education is to foster 'learning' which, in contrast to 'teaching', is something a person does for himself or herself and Hatcher (1997) states that self directed learning offers a deep level of understanding.

In view of the potential for interactive computer resources to promote self directed learning, it was considered that students' learning outcomes could be significantly improved by development and use of an IT package incorporating interactivity as well as high quality MR images.

Learning resource project

A Committee for University Teaching and Staff Development (CUTSD) Individual Grant was applied for and gained in 1997 to develop a PC based CD-ROM teaching and learning resource. The project, 'Interactive Computer Package for the Teaching of Magnetic Resonance Imaging to Medical Imaging Students', was undertaken for a two-year period.

The initial part of the project was to evaluate software development platforms to meet the needs of the teaching and learning resource. A major fault with available 'off the shelf' development packages was the limitation of their image viewing capabilities. MR images are displayed in shades of grey and can have over 1000 different grey scale values within the image. Typical image formats (jpeg, gif, tiff) that were capable of being displayed in these 'off the shelf' packages allowed the display of only 256 shades of grey.

A specifically designed viewing and image modification program was considered to provide the best solution to be able to give students the quality of images seen in the clinical environment.

Clinical MR images of the brain were chosen as the basis of the learning resource. MRI has the capability of obtaining images in many anatomical planes such as the axial, coronal and sagittal planes. The axial plane was chosen as undergraduate medical imaging students have more experience with images obtained in this plane through their involvement with CT.

Over 1,100 MR images were obtained from a single volunteer on GE Signa 1.5T MRI units (GE Medical System Australia Pty Ltd, Botany) at the Royal Children's Hospital, Melbourne and Wagga Medical Imaging, Wagga Wagga. These were obtained using a small change in each of the MRI parameters that control MR image contrast and quality.

The result was the development of the teaching and learning resource, *MRI Concepts*. This CD-ROM based program allows students to access high quality clinical MR images through a PC running *Microsoft Windows 95/98* or *Microsoft NT 4.0*. Figure 1 shows the typical and familiar 'Windows' design and features available to the user.

A reference group of clinical MRI users, MRI educators and a third year medical imaging student was established in 1997 to review the development of the software teaching tool and provide

feedback to the designer and programmer. The third year student cohort of 1998 was also used as a trial group to evaluate the use of *MRI Concepts*. These students completed survey forms on the useability of the material and their perceptions of the ability to comprehend it.

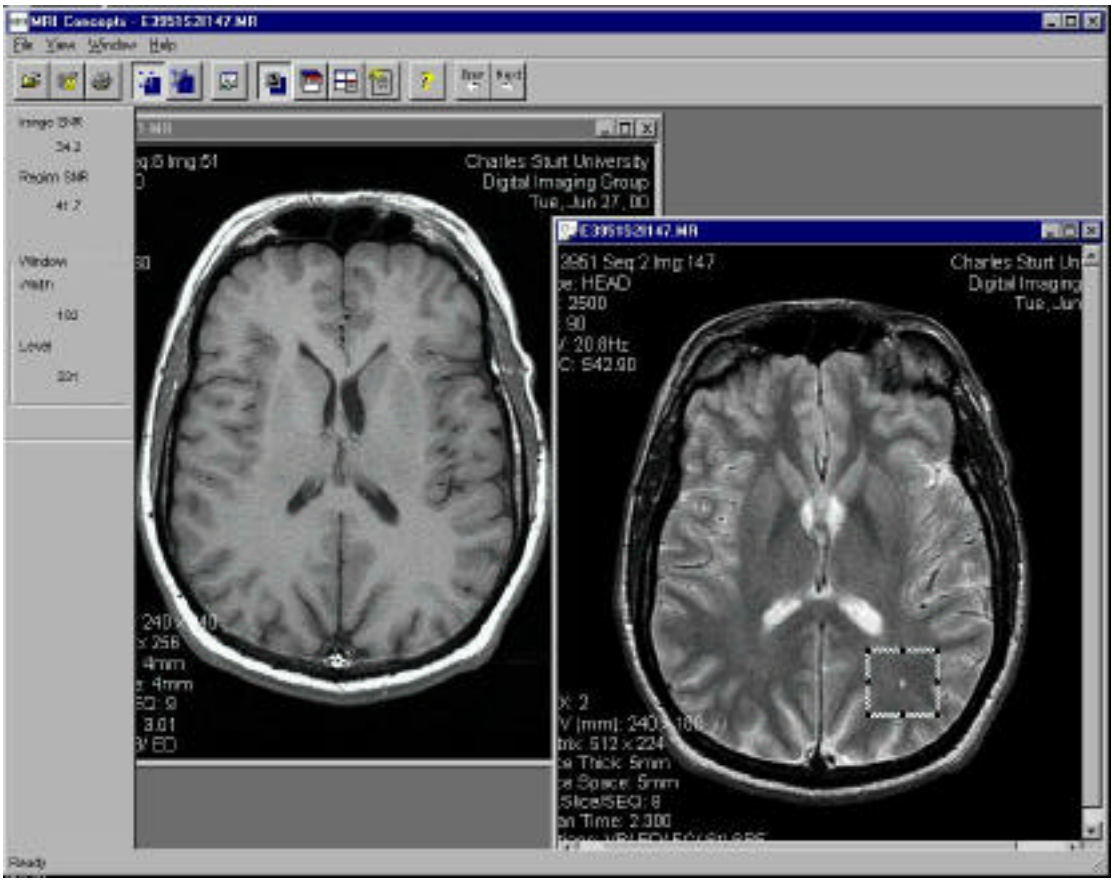

Figure 1. *MRI Concepts*: A *Microsoft Windows* compatible program

Teaching methods

MRI Concepts is used to supplement the teaching of MRI physic and principles. Formal classroom teaching methods are still used to provide students with the majority of the educational content requirements. References to texts and web sites complement the formal material. *MRI Concepts* is provided to each student on a CD-ROM. Tutorial periods are allocated for access to computers. A practical manual aids the students in using the program and a series of tutorial exercises provides a series of tasks to be completed. The tutorial exercises are designed to allow flexibility in outcomes. This encourages students to wander and delve into the program and assess many and varied MR images.

Use of the *MRI Concepts* program also allows learning location independence. Students can access the program at home or outside the allocated tutorial periods. Use of this CD-ROM has allowed convergence of the teaching strategies used for distance education with those used for on-campus students.

Evaluation

The evaluation of the learning effectiveness, when implementing a new teaching strategy or resource, can be difficult. It was decided that the evaluation of learning outcomes should be undertaken to assess improvements of comprehension arising from the use of *MRI Concepts* and associated tutorial exercises. Learning outcomes through the use of *MRI Concepts* and tutorial exercises were identified as:

- identification of a Spin Echo (SE) image sequence in MR imaging;
- identification of MR contrasts of T1, T2 and PD in a MR image;
- identification of parameters that affect MR contrast and image quality;
- analysis of the results of changes in MR image quality when MRI parameters are changed; and
- determination of the changes in Signal to Noise Ratio (SNR) in the MR image when parameters are changed.

The *MRI Concepts* program was used at the same time as formal classroom teaching of the MRI physic and principles, due to timetabling constraints. It was therefore decided that the evaluation of the change in comprehension in each student following the use of the *MRI Concepts* program, could not be undertaken without being confounded with increase in comprehension associated with formal class work.

The most appropriate method to assess student comprehension was to assess different cohorts of students. The 1997 cohort of medical imaging students did not have access to the *MRI Concepts* as the program was still in development. Assessment questions relating to the expected improved learning outcomes were identified in the students' examination answer scripts. The students' responses to these identified questions were marked and the results were recorded. The 1998 and 1999 student cohorts, who used *MRI Concepts* as a part of the subject material, were likewise assessed and their results recorded.

Results

A plot of the 3 student cohorts' results can be seen in Figure 2. This frequency distribution data appears to display differences in results of the 3 cohorts. The mean values and the spread of the results, seen in Table 1, would suggest differences in results between the 3 cohorts. To compare the results, statistical comparisons were undertaken.

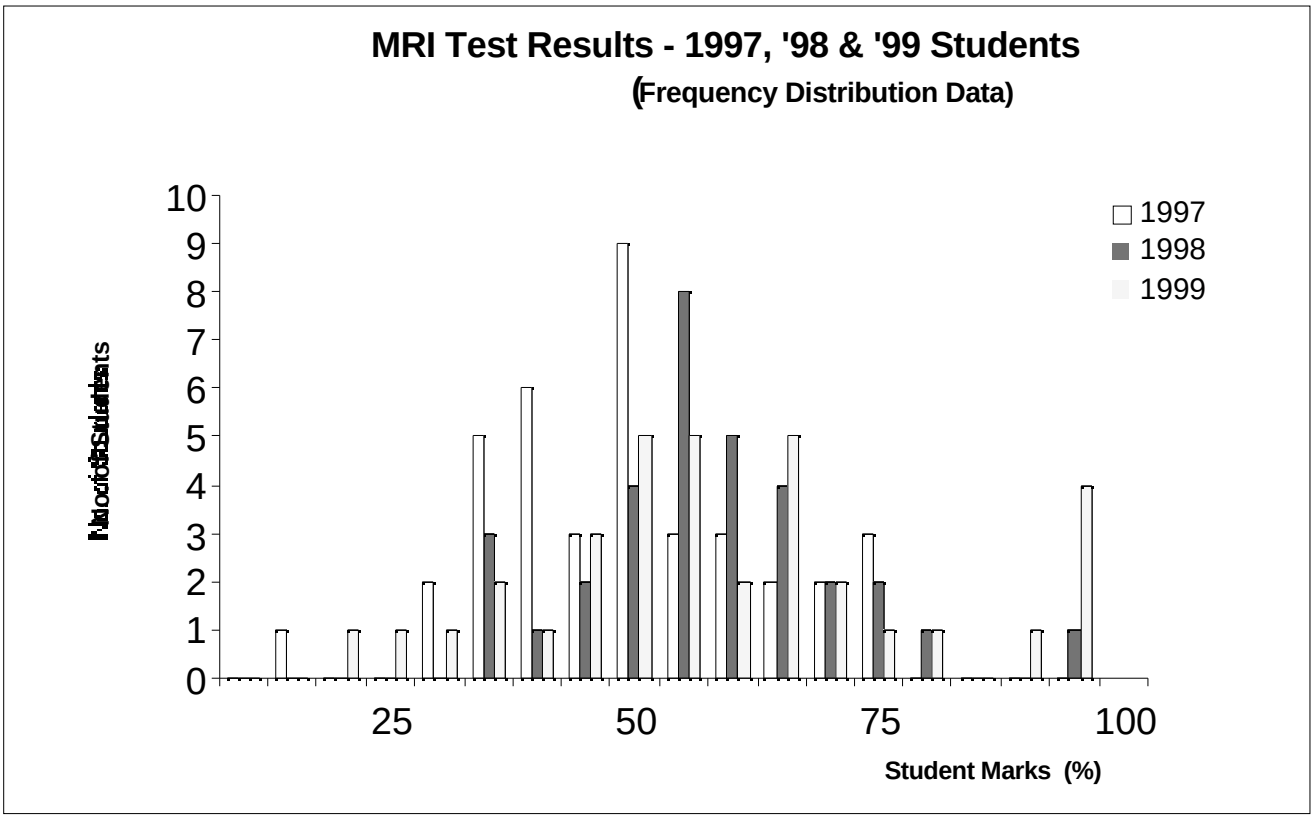

Figure 2. Frequency distribution plot of student results for 1997, 1998 and 1999

t-Test: Two-Sample Assuming Unequal Variances *Comparison of 1998 & 1999 Results to 1997 Results*			
	1997 Results	*1998 Results*	*1999 Results*
Mean	52.1	60.2	61.7
Standard Deviation	14.1	13.0	19.7
Observations	39	33	35
Hypoth. Mean Diff.		0	0
t Stat		-2.5196	-2.3971
P(T<=t) one-tail		0.0070	0.0098

Table 1. Comparison of t-Test statistics of 1998 and 1999 results to 1997 results

The mean mark for the 1998 and 1999 student cohorts were significantly higher than the mean for the 1997 cohort (one-tail t-test, p=0.007 for comparison of 1998 to 1997; p=0.010 for comparison of 1999 to 1997; see Table 1). However, the means for 1998 and 1999 were not significantly different (p=0.694; see Table 2).

t-Test: Two-Sample Assuming Unequal Variances		
	1998 Results	*1999 Results*
Mean	60.2	61.7
Standard Deviation	13.0	19.7
Observations	33	35
Hypoth. Mean Diff.		0
t Stat		-0.3950
P(T<=t) two-tail		0.6943

Table 2. Comparison of t-Test statistics of 1998 results to 1999 results

Discussion

The comparison of student results between various cohorts shows a difference in comprehension of expected learning outcomes that have resulted from the use of *MRI Concepts*. Those students who had access to the *MRI Concepts* program and tutorial exercises showed improved comprehension over those students who did not have access to this teaching resource. Although comparisons of students results could not divulge reasons, such as lower group intellect in the 1997 cohort, student aversion to subject content or teaching methods, the author's observations of the students during use of the CD-ROM package suggest that the improved learning shown results from the use of *MRI Concepts*.

The use of a CD-ROM based program, such as *MRI Concepts*, allows the student to gain a nexus between the learning and the clinical situation. *MRI Concepts* also provides the ability for students to visualise clinical quality MR images. Thus, the interactivity of the program and the ability for students to 'wander' deeper than tutorial material, also allows students to engage in deep-level learning. From the combination of deep-level learning and relevant context of the learning, improved learning outcomes would be expected.

With the integration of *MRI Concepts* and tutorial exercises, learning can progress at the student's own pace. Students can also undertake the learning outside formal classroom times, when they feel their learning experience will be optimised. Students can gain a 'sense of ownership' in their understanding of the material when these factors are allowed. These lead to deep-level learning and a higher level of retained knowledge.

The use of computer programs based on CD-ROMs allows equity of use for both distance and internal students. Teaching practices have differed between internal and DE student cohorts due to physical location differences. Now these practices are beginning to converge. The differences that existed, mainly teaching practices and the ability to provide MR images of the same quality, are disappearing. The medium to visualise MR images is the same, as the quality of those images. *MRI Concepts* provides a teaching and learning resource that any student can access.

Previous teaching practices have been enhanced by the introduction and use of *MRI Concepts*. The teacher's role now is more towards a facilitator of learning rather than the 'fountain of all knowledge'.

Conclusions

MRI Concepts has proved to be a valuable teaching tool for the teaching of MRI to medical imaging students. It has proved a valuable learning resource for students and enhanced learning outcomes for those students. Specifically, the use of *MRI Concepts* and the tutorial exercises improve the level of knowledge of students in the areas of MR image contrast and MR image quality.

The use of the CD-ROM based program has added flexibility in the delivery of the subject content. Students can undertake the tutorial tasks at their own convenience and in a location of their choosing. Students are now not restricted in access to clinical quality images and do not need to be seconded to a clinical MRI unit to gain an understanding of the concepts of MRI parameter changes on MR image contrast and quality.

The *MRI Concepts* program is a teaching and learning tool. Adoption of tutorial exercises to meet specific teaching objectives would allow this program to be used in any institution involved in the teaching of undergraduate medical imaging or introductory postgraduate MRI courses.

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