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Using multimedia elements to change student mental models of colour vision deficiency

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Using Multimedia Elements on the Web to Change Student Mental Models of Colour Vision Deficiency

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The online environment offers many opportunities for students to interact with each other, unit materials and resources, and for lecturers to inform students of issues regarding their main course of study. One of the weaknesses of teaching and learning in the online mode, however, is that lecturers have difficulty in identifying misconceptions and imperfect mental models in their students.

This paper reports on a study being conducted by a West Australian university in the use of small e-learning modules developed in Quicktime video to change or strengthen students' mental models – in this case their mental model of Colour Vision Deficiency (CVD), or colour blindness. It is hoped that one of the outcomes of the research will enable academic staff to create their own Quicktime based e-learning modules, using very simple technology, to inform and modify student perceptions on any given topic.

As courses move towards the online environment, many issues become apparent. One of these is how can teachers identify their students' mental models and, even more importantly, how can erroneous mental models be corrected.

The impetus for this study came from the fact that one of the authors taught her students about the effects of colour blindness on web site accessibility and software design. It was found that, although students had access to a colour blind person (in the form of a fellow student), many did not understand the concept of colour blindness and the effects on perception of text and images in web sites.

An informal review of the students found that many of them felt that blindness to colour resulted in a blindness to objects. This misconception was particularly prevalent among Asian students. A review of the literature highlights the fact that colour blindness is most prevalent among Caucasian males (8%), and very few Caucasian females (0.4%) (Jacobs, 1981; Marcus, 1992). It is an increasingly important area of website design, with the World Wide Web Consortium (W3C) guidelines containing 833 references to colour blindness.

For the e-commerce students, many of whom would be destined to be managing e-commerce projects, colour blindness was considered to be an increasingly important aspect of accessibility. Colour blindness (or Colour Vision Deficiency – CVD) was also chosen as a topic for the experimental module because of the interesting and diverse mental models students displayed on the issue.

An exhaustive literature review has found a paucity of research into e-learning and mental models, and the use of e-learning modules in tertiary education. This paper will look at some of the issues surrounding mental models and online teaching, as well as outlining a proposed solution for helping to overcome incorrect student mental models in a university online teaching environment.

Mental Models

When Johnson-Laird, (1990) states that a "primary source of mental representations is perception" (p 1), he is using "mental representations" as a synonym for "mental models", but, as outlined by Johnson-Laird and Byrne (2000), the term has a narrower referent in terms of thinking and reasoning. Mental models can be constructed from, not only perception, but also imagination or comprehension of discourse, and they can be abstract or visualised (Johnson-Laird & Byrne, 2000).

Mental models may also be constructed from real, imaginary or hypothetical situations, and the mind builds small scale models of reality that it uses to anticipate events, to reason and to underlie explanation (Craik, 1943). In constructing a mental model a mental simulation may be 'run' in order to draw conclusions. This is distinct from the notion of the mental model as an image, which is considered to be a one-off representation, such as reconstructing a scene (Preece, 1994). Barker et al (1998) examine the development of mental models through appropriately designed teaching and learning activites whereby it is possible to adapt a mental model through reflection, remediation and reconstruction processes. Mental models are described as dynamic and adaptable. A mental model can change during the course of a conversational situation as new knowledge is acquired (Barker et al, 1998). Learners progress from having a naïve mental model through to an expert mental model as their understanding of a concept deepens, particularly when supported with open-ended learning situations and suitable scaffolding (Oliver & Hannafin, 2001).

Every teacher should have an understanding of effective and ineffective mental models so that the correct kinds of scaffolding, modelling and coaching can be included in learning environments. Solving situated, ill-structured problems in different settings requires the solver to use complex and diverse mental representations (Jonassen, 1997). The possession of correct mental models provides a natural way of inferring probabilities and allows students to fulfill decision making tasks as well as providing a means of meta reasoning (Johnson-Laird, 1998). Johnson-Laird et al (1998), conclude that reasoning is easier from one model than from multiple models, and become semipermanent tacit 'maps' which students are able to hold in their long-term memory.

The Problem

One of the authors is responsible for a web usability class, whereby Electronic Commerce students have to design web interfaces that are usable and accommodate people with disabilities. It is therefore essential that they have a correct mental model of all the issues (in this case colour blindness) and an understanding of their effects on Web users.

Many of the students had no concept of the implications of being a colour blind Web user. Even the opportunity to interview and observe a colour blind peer did not seem to have an impact on their understanding. Several students (14 of the total 103) believed that colour blindness was "object blindness", in other words, a colour blind person would not see traffic lights at all. Other students believed that a colour deficient person only saw in black, white and shades of grey. A demonstration of the problem of knowing when a mobile phone was recharged (was the recharging light red or green?) helped the majority of students to gain an insight into the problem, but many students still used blue text or red and green elements (with no secondary cues) in their interface designs.

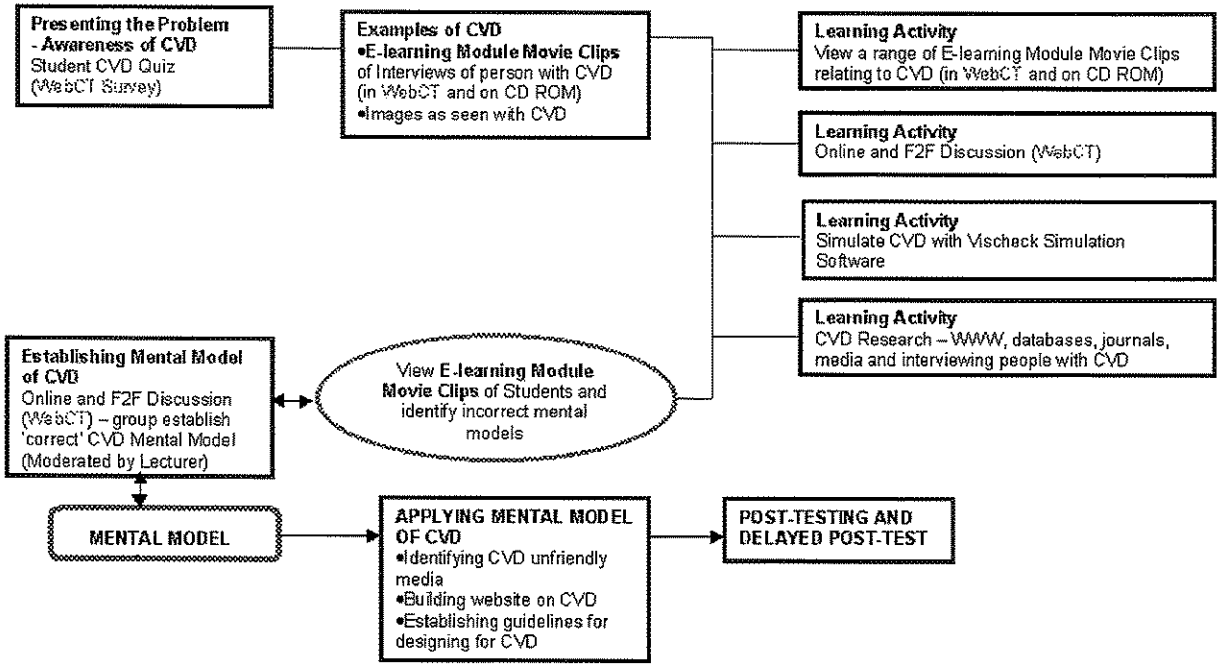
For an in depth explanation of the issues of CVD readers of this paper are directed to a discussion on colour blindness in the mail archives of the W3C Web Content Accessibility Guidelines Working Group found at http://lists.w3.org/Archives/Public/w3c-wai-gl/1998JulSep/0160.html. W3C, the World Wide Web Consortium (http://www.w3.org/), develops common protocols that promote evolution and interoperability of the WWW, and sets standards for Web accessibility.

The proposed solution

In an offline learning environment students are able to discuss issues with lecturers and peers, and in the case of the CVD issue, were able to interview a colour blind student. However, these options are not available to online students studying in remote or rural areas. To offer online and external students a similar learning experience the authors set out to develop a series of learning modules that could be used in conjunction with a WebCT or Blackboard learning environment, or to delivered on CD ROM for students without internet access.

Supporting the project was a Teaching and Learning Grant received by the authors in 2001 to work on the development of reusable interactive e-learning modules to support students' learning of new applications, mastery of difficult concepts and modification of mental models, such as the colour-blindness issue as described earlier. The project included designing prototype modules with interactive elements from a variety of sources implemented in Quicktime with audio and text annotations. One of the key aspects of this Teaching and Learning Grant project was the requirement that the e-learning modules be easily developed by faculty staff without any multimedia programming skills or high tech equipment. This introduced an additional challenge of having to think in terms of what is 'easy to create, effective and accessible' for most staff venturing into online teaching, rather than considering state of the art high tech options that can not be easily modified or replicated with minimal cost to a faculty.

Figure 1: Colour Vision Deficiency (CVD) Awareness Problem



Three prototype e-learning modules were designed and developed using the example topic of 'Awareness of Colour Vision Deficiency' which was known to be a problematic topic for students studying Web design and results in a range of student misconceptions. Figure 1: 'Colour Vision Deficiency (CVD) Awareness Problem' illustrates the application of e-learning modules designed for this topic in combination with a range of learning activities.

E-learning Module 1 – The CVD Experience

The first e-learning module was designed using video clips of an interview with a person with CVD. The module identifies the type of CVD (red/green) and displays a range of images which are then described by the person with CVD with their perceptions of the colours that they anticipate are in the picture. The e-learning modules allow the images to be displayed to the user in both their actual colours and in a format simulating the colours actually seen by the person with CVD. Students are presented with examples illustrating cases where CVD may not pose a problem (ie 'grass is always green') and cases where CVD results in quite a different interpretation of the colours and their meaning (ie Blue waves in an image represent water to a person with CVD. But what if the waves are actually red? What do they symbolise then, and do they actually symbolise anything at all?). The students are also able to observe the effects of surrounding colours and the fact that a "haptic illusion" can occur where the senses are tricked.

E-learning Module 2 – Student Perceptions of CVD

The second e-learning module comprises a series of student interviews whereby students in pairs were asked to interview each other to find out what they know about CVD. The resulting student interview video clips illustrate a range of responses ranging from knowledge of aspects of CVD to total misconceptions and clearly erroneous mental models of CVD. Figure 2 lists the series of questions used in the student interviews.

1. What do you think colour blindness is?
2. How do you think it affects people?
3. What are the problems associated with colour blindness?
4. Do you know the different types of colour blindness?
5. What do Red & Green colour blind people see?
6. What do Blue and Yellow colour blind people see?
7. What is your major/ double major?
8. Do you think you need to be aware of colour blindness in your proposed field of work?

Figure 2. Student Interview Questions

E-learning Module 3 – CVD and Web usability

The third prototype e-learning module presented the students with examples and issues showing the importance of an awareness of CVD in the field of designing for web usability. In this module they saw examples of webpages and how these are viewed by a person with CVD.

As stated earlier, Figure 1 shows potential applications of the modules with an introductory Web design class. Students were initially asked to participate in a pre-test survey which, in the form of an online quiz, collected answers to questions designed to establish their level of awareness of CVD and a snapshot of their current mental model of CVD. The results of this survey were anonymous, but students were asked to identify themselves with a 'nickname' which was used both in this pre-test survey and then in the subsequent post-test surveys and allowed the researchers to match all responses relating to the same student and establish whether a change of mental model took place.

Following the pre-test students were presented with the first e-learning module featuring interviews with the person with CVD and images as viewed with and without CVD. Students were then given the opportunity to discuss their own views of CVD face-to-face in the on campus group, or online for both the on campus and external groups. They were also given the opportunity to further research the topic of CVD, and CVD issues relating to webpage design through a series of web links and were offered opportunities to conduct their own research via a range of sources both online and print-based. Students who were keen to further explore the way images appear to a person with CVD were directed to the Vischeck website to download or use the online CVD simulation software. It was hoped that they would thus become alerted to the issues of CVD and interested in finding out more about it, particularly in relation to their chosen field of study which included in most cases website design and marketing.

Students were then presented with the second e-learning module which featured student interviews on the topic of CVD as described above, and asked to identify the incorrect mental models of CVD that become evident through the student interviews. At this point students were also encouraged to try to establish what the 'correct' mental model of CVD is. For example, what does a person with red and green colour blindness see when presented with items that are red and green? They were given the opportunity to discuss this face-to-face or online and collectively agree on what the correct mental model should be. The lecturer moderated the discussion and identified any areas of difficulty and misconceptions that may lead to the development of an erroneous mental model.

The third e-learning module was used to alert students to some of the pitfalls of designing websites without considering CVD and to give them some guidelines to follow. From this point onwards students were expected to start applying their knowledge of CVD in webdesign. A range of learning activities that could be undertaken by the students were considered, starting with an exercise in critiquing websites from the point of view of catering for people with CVD; group projects to build a website about CVD; or establishing guidelines for website designers to design quality websites that are user-friendly for colourvision deficient users.

Students subsequently completed the Awareness of CVD survey for the second time and the data collected was analysed to identify any change in their mental models. Students were exposed to the CVD problem in the early part of the semester and a delayed post-test survey was taken in the final week of semester allowing the lecturer to establish whether there was any further change in student's mental models of CVD.

Implementation of the e-learning modules

Technical investigations resulted in the e-learning modules being produced using a combination of Quicktime Pro and Microsoft PowerPoint 2001 (Macintosh) which supported the embedding of Quicktime based video clips within a PowerPoint presentation (allowing for the easy addition of text and graphics). This was then converted with a simple save operation into a Quicktime movie with embedded Quicktime video. This process gave rise to a non-hightech development solution accessible to staff using Office 2001, resulting in the quick and easy development of Quicktime Pro e-learning modules. The resulting Quicktime movie can be edited with Quicktime Pro and additional tracks added to the finished product at a later date. However, the use of PowerPoint as the initial e-learning module design environment was considered by the designers to be particularly attractive as it is a tool that most academic staff are comfortable with using and hence the opportunities for takeup amongst staff of e-learning module creation is promising. E-learning module design could range from very basic to potentially sophisticated depending on the designer's creativity and resources available. For example, Quicktime movies created based on PowerPoint presentations can include multiple images per slide, embedded filmclips with static images in the background, sound and voiceover tracks, hotlinks to other Quicktime movies and hyperlinks to websites. With the potential to develop Quicktime movies using a range of other sources and the ability to edit these to combine movie segments into sophisticated e-learning modules, we believe that this provides a foundation for a wide range of development opportunities that are in essence a mainstream easily accessible solution.

The Quicktime-based modules can be provided to students on CD ROM, downloaded from a WebCT or Blackboard environment, delivered online in smaller segments or streamed to students.

We chose Quicktime as an e-learning module vehicle for students primarily as it was non-platform specific, very easy for students to manipulate and particularly offers students the option to return to specific areas of an e-learning module to replay segments as many times as they wish. A negative aspect of this solution was the potentially large file sizes of the final Quicktime movie modules. We address this problem by providing full length modules on CD ROM with only short 'teaser' segments available online.

Survey Results

Figure 3: E-learning module trial illustrates the evaluation process. 103 students were tested on the e-learning modules. Preliminary results indicate that 93% (97 students) of the students appeared to completely change their mental models over the short term (6-8 weeks), acquiring a fairly accurate picture of what CVD involved. 5% of students

did not change their mental model, and 2% achieved a worse score on their post-test than on their pre-test.

In the pre-test 97 students scored between 0% and 20%, 48 of them having never heard of colour blindness. These students did therefore not have a prior mental model, but immediately began to form one from the term "colour blindness". In their written descriptions of colour blindness or colour vision deficiency, they hypothesized with explanations such as "if a person is colour blind, and there is a girl in a red jumper, the person will not see the girl", and "instead of seeing golden arches at McDonalds, a colour blind person might see pink arches or something" were common. 14 (13.5%) students interpreted colour vision deficiency as not being able to see colour at all. Of the remaining 6 students, 1 had CVD, so scored high in the test, and the other 5 scored between 70% and 90% on the test.

All of these students were tracked for the post-test, and scored between 75% to 95%. Their written explanations of colour blindness were more cogent, and many referred to the video of the interview with the colour blind person.

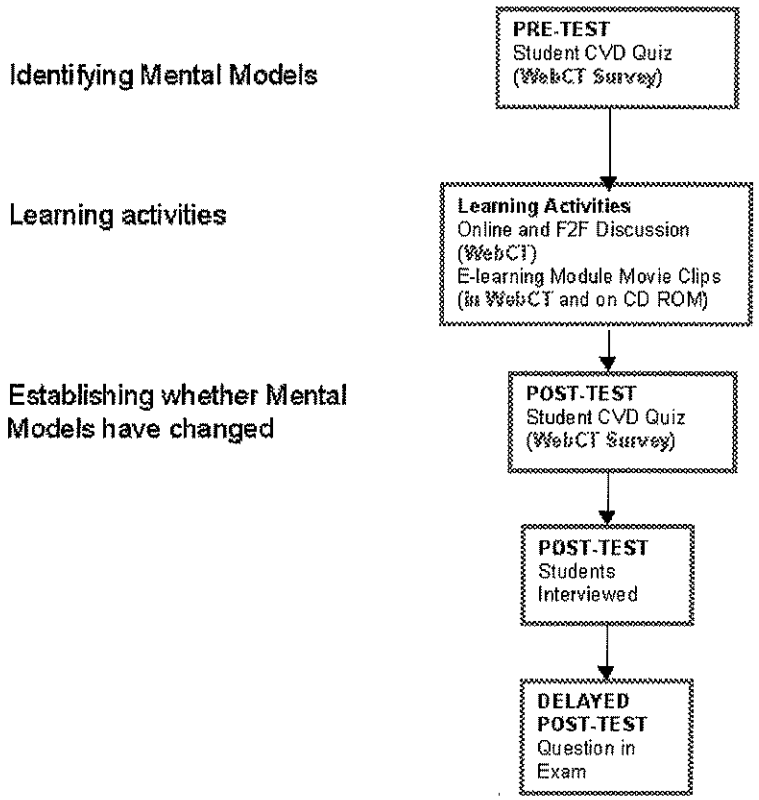


Figure 3. E-learning module trial

63 students have so far undertaken the delayed post-test, and of these, 58 students achieved identical scores to their post-test. This represents almost 95% of students having acquired the correct mental models for CVD (2% more than in the post-test).

The growth in percentage of correct scores was not explicable without interviewing the students. This is proposed in the next stage of the evaluation process.

Students were asked about the learning process and 100% claimed that they enjoyed using the modules, that they could identify with Peter (the interviewee), and that he made CVD concepts understandable. About 60%, however, disliked the student interviews, claiming that they would rather view videos of people with CVD, than other students talking about their own mental models. Future iterations of the unit will reduce the emphasis on students and include another interview with a person with a different type of CVD. The students were also interested that the simulations did not always match with what Peter saw. This had the potential to create problems with their web page design, so a further, small module on the impact of colours on each other was introduced.

When asked, the students generally felt that their learning experience had been enhanced by the use of the e-modules. As one student said: "the pre- and post-test gave me concrete evidence of how .... I didn't know much, and now I can see that my understanding has changed incredibly". Another stated: "you could do all this in a lecture, it would take twice as long to say it all, and it wouldn't have the impact – Peter's comments like the grass comment, came back to me in the exam, it made the discussion on the question so easy".

The students also enjoyed being able to review the material, as evidenced by the following comments: "I went over it a few times and then I read the articles you gave us side by side with the video, it made them [the articles] more meaningful", and "Much better than just listening to a lecture (no offence), but you can't hit the replay button if you fall asleep for a minute. I used the videos a few times, specially before the exam. It would be good if everything could be done like this, but I can see it's a bit impractical". Another student, who was studying completely online, had the following to say: "they [the videos] broke up having to read the articles. I looked at the videos, read the articles, then looked at the videos again. I felt less left out somehow".

There were two students who did not enjoy the videos: "I would rather read the articles than look at a video, didn't add much", and "they were ok, I still can't see why I need to know this stuff. If someone's blind, why do we have to worry?". This student was one of the few whose mental model did not change!

Conclusions

Overall, it was felt that the improvement in the mental model, and subsequent improvement in the exam score for that topic, justified the effort in making the videos. The workshop on e-modules conducted for staff at ECU has now produced e-modules in other units, and is the topic of a further grant application by a different group of staff.

Although the e-learning modules utilise simple technologies, they were found to enhance student engagement with the topic, and did succeed in increasing their understanding and fundamentally changing their mental models of CVD.

The project addressed an area of teaching and learning that is of concern to most lecturers teaching externally and online, that of addressing incorrect mental models. It will also be useful in teaching difficult concepts online, as it will give students an alternative source and format of information. As the e-learning module solution developed is not high-tech, and does not require any interactive multimedia programming or technical expertise, it is a solution that will be accessible to almost all staff. A facility for academic staff to be able to generate and edit digital video footage is being setup in the Faculty of Business and Public Management at Edith Cowan University. This facility will greatly improve the opportunities for development and overall accessibility of video media in this faculty. Staff will be able to develop their own e-learning modules with or without embedded Quicktime Video and deliver these to students in a variety of formats, on CD ROM or online. The authors intend to run a series of training workshops to assist staff in creating their own e-learning modules and to provide educational design advice in adapting the CVD model solution to other areas where lecturers wish to address learning difficulties and misconceptions.

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