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The development and use of background mathematics materials needed by students for engineering programs at Central Queensland University

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Abstract

This paper seeks to explore issues inherent in the development of learning materials for the Mathematics Learning Centre (MLC) at Central Queensland University (CQU). The materials were designed to provide a range of learning experiences in order to enhance students' understanding of mathematical content and concepts in background mathematics for Engineering programs at CQU. A Mathematics Skills Audit test and web-based materials were prepared to assist the students. The paper also presents a number of guiding principles for the design and development of learning materials used by the MLC.

Introduction

"Recent developments in multimedia technologies and software, and enhanced networking facilities through the Internet, have led to new and exciting opportunities for hypermedia systems development" (Oliver & Herrington, 1995, p. 8). This paper seeks to explore issues inherent in the development of effective web-based materials for the MLC at CQU. Specifically the paper explores the opportunities, possibilities and constraints with regard to implementing web-based materials for mathematics. The paper also presents a number of guiding principles for designing and developing those materials.

The development of effective web materials for the MLC

The MLC is a support unit which provides assistance to students who are experiencing difficulty with the mathematics or the quantitative component of their program at CQU. Students from all the faculties requiring mathematical support are able to access the MLC for both individual and group tuition, according to their needs. The MLC also offers a range of preparatory courses in mathematics for enrolled and enrolling students undertaking course work with a mathematical component.

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Two of the most important student characteristics, which influence the teaching/learning process used at the MLC, pertain to the students' prior skills and knowledge and their personal learning needs. Students who use the MLC usually tend to have had limited mathematical opportunities throughout their schooling, and encounter difficulties understanding abstract and complex concepts. In addition, students may have had negative mathematical experiences and may become apprehensive or anxious when engaged in solving mathematical problems or when using mathematics. The foregoing characteristics often contribute towards "reluctance on behalf of the students to access and utilise technology within their mathematical studies" (Fuller, 1994, p. 662).

However, there are also a number of students who access the services of the MLC who have sound mathematical skills and knowledge and who require only limited support to enhance and extend their mathematical understanding and technological competencies. Many of these students have undergone a range of mathematical experiences and may be confident to engage in further mathematical challenges under the guidance of a tutor.

Mathematics is a dynamic discipline with a range of intertwining concepts, which are able to be reflected in web program designs, whereas paper text provides a very linear approach to mathematics learning materials. The World Wide Web affords opportunities to present the material in a more fluent manner, similar to the nature of mathematics itself. Through this structure "students can select and access material and content according to their needs" (Webster & Hackley, 1997, p. 1289).

The design of web-based materials enabled the use of various media such as text, sound, graphics and video either individually or in combination, providing a range of learning opportunities for students. These features also provide for a range of learning styles and allow students technological access to their preferred medium for learning (Alessi & Trollip, 1991; Fuller, 1994, p. 664). For learning mathematics, the website features are particularly pertinent as they allow students to internalise and consolidate concepts through a combination of auditory, visual and kinaesthetic cues. For example, when exploring algebraic equations using the graphics calculator, students are able to read the instructions, view the calculator procedures, engage in a simulation activity and practise their skills through a variety of interactive exercises, on which they receive instant feedback.

Another significant advantage of the Web is that it enables almost unlimited access to a range of other sources to support learning. For instance, often when studying mathematics there may be a need to refer to a range of authoritative sources to consolidate and/or reinforce understanding. With the Web, students are able to experience the immediacy of this task, accessing a variety of sources appropriate to their needs. For example, when using the graphics calculator in solving mathematical problems, students may wish to investigate the facilities and features of the instrument in order to support their endeavours. This task is enhanced through access to a number of websites which provide both information and learning experiences suited to this requirement.

The use of the Web can also serve to motivate students. For example, students often experience difficulty gaining adequate motivation for study when confronted with textbooks that are very technically oriented and that contain large sections of explanation and proofs and offer little opportunity for active engagement with the material. Frequently reading these materials becomes an onerous task. This is often alleviated when mathematical content is presented on the Web, as it requires

students to interact regularly with the content, reflect upon their learning and engage in a range of hands on activities.

Despite the foregoing, there are also a number of issues that need to be considered when using the Web for teaching/learning purposes. The most apparent problems in using web-based materials for mathematics would be in limiting students' learning opportunities if students are unable to access this technology. Clearly this is an equity issue and needs to be addressed through funding considerations and the provision of resources appropriate to the students' learning needs.

Secondly, the materials developed on the Web are not portable, as is print based material, and require students to have adequate facilities to support this learning medium. Hence both students and teaching staff need to ascertain the appropriateness of this technology to the learning context and to accommodate appropriate administrative and logistical requirements. The web-based materials were made available on a compact disc (CD) so students who do not have Internet access could still use the materials.

Thirdly, account needs to be taken of the features of the Web by the developers when it is the vehicle that delivers the instruction.

> It is the nature of the learning-support environment that has the biggest impact on what is learned. Instructional materials that enable free browsing with little cognitive demand are likely to be less effective than those where the students are compelled to complete tasks and completion is monitored and checked. (Oliver, 1998, p. 50)

Hence issues of access and equity, combined with the unique operational features of these two information communication technologies (ICTs), constitute major considerations in the design of programs, which provide feedback mechanisms and opportunities to monitor students' understanding of content.

Instructional principles for the development of web-based materials at the MLC

Taylor (1998) suggests: "…in the past twenty years, there has been a significant expansion in the availability of a wide range of technologies with the potential to improve the quality of teaching and learning" (n.p.). These advances have been accompanied by job specialisation, a multifaceted approach to curriculum design and development and "opportunities for interactivity and access to instructional resources provided by the computer communications networks" (Taylor, 1998, n.p.).

However, in the light of these developments, it is important to examine further the inherent meanings ascribed to the concept of technology. Millwater (1988, p. 2) identifies "technology" as the "actions of peoples", whereby "change can be affected in the physical environment and most importantly, the social and ideational environment". In this sense, technology is essentially a process in which human behaviour is central. Consequently, if an educator is to accommodate learners' needs and appreciate the skills, experiences and knowledges that they bring to the learning situation, it is critical that s/he is able to harness the invasive influences of technology. Whether applied to the classroom context or to open and

flexible modes of learning, these considerations are integral to the processes and practices of learning.

A number of guiding principles have informed the design and development of web-based study materials for students who use the MLC. These principles are mainly based on the adult learning work of Knowles, Holton and Swanson (1998) and Entwistle and Ramsden (1983) and the principles of the use of computer-based materials (Alessi & Trollip, 1991). These aspects will now be briefly considered.

- Adult learners at the MLC are considered experiential learners who need programs that are meaningful and relevant to them. Adult learners like to be involved in the learning process facilitated in a climate of respect. A Mathematics Skills Audit test is used to determine the learner's background knowledge and understandings of mathematics**.**
- Adult learners see education as a process of developing increased competence to achieve their full potential in life. They want to be able to apply whatever knowledge and skills they gain today to living more effectively tomorrow. Accordingly, learning experiences should be organised around competency development categories.
- It is a normal aspect of maturation for a person to move from dependence towards increasing self-direction, but the rate of change to self-directed learning varies among people, depending on their backgrounds. Thus it is important to provide independent learning materials appropriate to a range of individual needs and levels of ability. Web-based materials should, as far as possible, be self-instructional and self-paced and contain self-assessment opportunities.
- As individuals grow and develop, they accumulate a reservoir of experience that becomes an increasingly rich resource for learning. Accordingly, web-based study materials should be activity-based and should promote experiential learning within a supportive learning context.
- Individuals become ready to learn something when they experience a need to learn in order to satisfy real life tasks or problems. Thus web-based materials should be relevant to the adult learner's own needs and encourage the learner to discover the need to know.

The CD/web-based support program used by the MLC

A web-based support program was developed by the MLC to cover the background mathematics for students in Engineering programs at CQU. The web-based support program that was developed is an activity based program and was designed to provide a range of learning experiences for students, in order to enhance their understanding of mathematical content and concepts. Learning materials were developed for use by both internal and distance education students. The content of the learning material was to be based on the background mathematics needed for the course Mathematics 1A offered at CQU in the autumn term. This course covers the essential concepts of algebra and differential and integral calculus via the analysis and solution of real world problems. The students enrolled in Mathematics 1A are from the Engineering, Applied Science and Education faculties at Central Queensland University.

The web-based program described above was implemented in the first term of the academic year at CQU in 2003. There are nine main sections in the support

program that can be accessed from a CD or from the URL http://dtls.cqu.edu.au/mlc/prepmaths.html.

Appropriateness and relevance of the content

The content was derived from the key mathematical concepts of the course Mathematics 1A. Consequently the materials are relevant to the students undertaking this course and meet their learning needs. Specifically the content highlights how the graphics calculator can be used for understanding mathematical concepts. This includes topics such as linear equations, trigonometric functions, vectors, matrices and complex numbers. When introducing the content in the web-based materials, links between the students' prior understandings and abstract concepts were planned to be made explicit using the graphics calculator, in order to maintain the relevance of the material to the individual.

Relevance of the resource to learners' needs

The students' identified needs, as determined by the MLC, provided the basis for the development of the web resource. These needs were identified by both the learners and the facilitators of the course Mathematics 1A. Consequently the module is very relevant to both the learner and the MLC as a 'support unit'. The resources were designed to accommodate a range of learning styles, prior learning experiences and technological competencies and are delivered in a flexible mode on a CD or online. This learning context provides a range of benefits in supporting student skills and abilities in order for them to participate competently in the course Mathematics 1A. Essentially the module provides a mathematical foundation from which to nurture the students' emerging mathematical abilities.
The Mathematics Skills Audit was designed to identify any weakness in background mathematics. The web-based material can be used by individuals to overcome gaps in knowledge and/or skill that were identified via the Mathematics Skills Audit.

Producing and maintaining the web materials

When this website was produced, particular attention was given to the micro- and macro-typographical features. These provided a range of considerations for the production of the module and are listed and discussed here.

Micro-typographical variables

Micro-typography is primarily concerned with the legibility of the website. Table 1 highlights the micro-typographical variables used and provides comments on why they were incorporated.

Table 1: Micro-typographical features

Typographical Variable	Website	Comments
Textual typeface	Arial typeface.	Comfortable reading font.
Type size	Main textual commentary has been tested so it can be viewed on 14 inch screen set at 600 by 800 resolution.	Research (Kemp, 1993) indicates that type size affects legibility and comprehension.
Use of bold	Bold face is used for headings and links and to introduce new terminology.	Bold face draws the attention of the reader to important information.
Use of capitals and lower case	First letter of each word in the headings, menus and figures is a capital letter.	Research (Kemp, 1993) indicates that the best approach is to set headings in upper and lower case type.
Heading	Headings are bold face.	Headings are bolded to provide visual cues about the forthcoming content. Headings aid the reader in navigating the website.
Method of textual composition	Main textual commentary is of justified composition.	Justified composition aids in the breakdown of the text, which enhances its readability.
Line length	Main textual commentary is of line length, ranging from 30 to 50 characters.	The line length enhances the text's readability and does not clutter the screen.
Colour scheme	Off white background – main body text. Light orange background – menu. Black text – all commentary.	White and orange screens provide contrast for black text and allow viewer to discern the information easily without undue interference from the colour scheme.

These features contribute towards the readability of the text and distinguish key information, facilitating learner comfort and interest levels. Furthermore, the background does not overwhelm the text, but subtly complements it. A feature of MLC webpages has been that the text is very simple in nature; however, it interweaves key elements to provide a cohesive and coherent piece of text.

Macro-typographical variables

"Macro-typography factors are mainly concerned with the spatial arrangement of the page elements taking into account technical, instructional and aesthetic considerations" (Kemp, 1993, p. 35). Table 2 provides an outline of these factors, specific to the website, with accompanying comments.

Table 2: Macro-typographical variables

Typographical Variable	Website	Comments
Page length	14 inch screen set at 600 by 800 resolution.	Allows for the print out or downloading of pages for future reference.
Columniation	Single column for main textual commentary and a smaller column for menu.	Aids in navigation and breaks up the page for ease of reading.
Vertical spacing	Single spacing between headings and text.	Distinguishes the heading from the text.
Paragraph separation	Single spacing between paragraphs.	Separates content and adds to readability.
Graphics	Sidebar menu presented in graphic form. Graphics saved as GIF files.	Graphics incorporated to breakup the text and add visual interest. GIF images can be viewed by all Web browsers and work best with images created in a graphics program.
Browser	Internet Explorer Version 5 browser.	Web page was tested using Internet Explorer 5 or higher to ensure the page could be viewed by a majority of users.
Navigation	Two navigation bars per main page. The number of clicks required to get from the main page to any other page on the site is four.	Two navigation bars on each page allow viewers to access the main points of the site. The number of clicks has been minimised to increase the ease of user access.

It is evident that, as multimedia becomes more common, more Web browsers and computers will support it. Currently, however, the bandwidth or modem speed of 28.8K to 56.6K is really too slow to use multimedia effectively. However, the use of CDs can overcome this limitation.

Student support

When students interact with the materials, there are a number of inbuilt mechanisms to support their learning. These are linked with student activities and examples with which they can actively engage. Based upon their perceived progress, students are then able to email their responses to the tutor or telephone to discuss any problems, concerns or ideas they may have developed.

Feedback

Students and work colleagues' comments provided valuable feedback and enabled the website to be refined and improved. One of the main problems associated with the materials related to delineating the essential content needed and moulding it into an appropriate format for the students to access and interact with easily. This task demanded considerable development time and effort in organising a presentation format to meet a range of student

needs and to accommodate a variety of learning preferences. Evaluation data obtained suggested that few problems were experienced by the users. In the future, it is intended to incorporate the use of multimedia into the program using QuickTime. Specifically videotapes of teaching segments will be used to illustrate mathematical content and specific teaching strategies for both students and work colleagues to access.

Conclusion

The program that has been developed has embedded a series of macro- and micro-topic features and instructional strategies to support students' developing understanding. Furthermore, the support program has been developed in accordance with identified student needs and provides a range of learning opportunities to accommodate student learning styles and differing skill levels. The feedback intimates that the program is attuned to the student and to the factors impacting upon her/his successful engagement in this support program and in the mathematics course that it was designed to complement.

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