Designing an interactive electronic book for first year university mathematics

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Abstract

What features of instructional design are most important in constructing an interactive electronic book for university mathematics? Can mathematics courseware be effective in promoting learning? Does interactive courseware have enough advantages to make it worthwhile as a supplement to the traditional lecture and textbook? Are production costs unavoidably enormous?

In this paper we focus on *Epsilon*, an interactive courseware developed for first year university mathematics. While trying to address the above questions we describe the aims, structure, and i mplementation of *Epsilon* and discuss the principles behind its several key aspects.

Key Words

Interactive courseware; First year university mathematics; Self-paced learning; Distance education; CD Rom; Toolbook.

1. INTRODUCTION: FIRST YEAR UNIVERSITY MATHEMATICS

Most university students undertaking mathematics subjects do so to learn skills needed in other disciplines, be they business, engineering, psychology or whatever. Some arrive at university with vari ous weaknesses in their mathematical preparation and many find first year mathematics difficult and rushed. Coming from a closeknit, co-operative, supportive and intense learning environment in the f inal year of secondary school, many students find it hard to adjust to large lecture classes or other rigid teaching modes, and to greater freedom; and suddenly the semester has finished! But univers ity funding militates against smaller class sizes.

Meanwhile, competition between institutions adds pressure on academics to cater for the many different learning styles of our students. In particular, lecturers are urged to reduce the difficulties o f transition from school to university, to help increase the success rate of all students, to diversify learning materials and teaching methods, to keep abreast of possible uses of new technologies; and to provide for mature age or part-time students, as well as those living in remote locations.

Certainly, our students' greater access to computer technology allows us to explore new alternatives for learning and doing mathematics. Graphing calculators and computer algebra packages are being used

learning and doing mathematics. Graphing calculators and computer algebra packages are being used more widely in first year.

At Monash University, the potential value of computer based instruction in supporting both distance education and on-campus students was recognised, but a thorough investigation of materials develope d around the world showed that no single existing mathematics courseware seemed suitable for our standard first level subjects and compatible with our university network environment. This, combined w ith the availability of good multimedia authoring software allowing free distribution of their runtime versions, led to the decision to develop *Epsilon*, an interactive instructional courseware for first year mathematics, tailored to the needs of our students. Existing models for instructional design ([1], [2], [3]) were used to guide the creation of *Epsilon*.

2. AIMS AND CONTENTS OF *Epsilon*

The main aim was to produce a computer based learning resource for first year students undertaking mathematics on all campuses or by distance education. These are science, engineering and computing s tudents at three campuses; distance education students live in all parts of Australia, and some overseas. The courseware would present mathematics in an attractive and interactive format, and be tail ored towards non-mathematics majors - the vast majority of our first year mathematics students. *Epsilon* would be designed for individual learning, suitable for

(i) self-paced supplementing and reinforcing of lecture material
(ii) assisting in group or individual tutorial sessions
(iii) revising for exams
(iv) supplementing printed materials in distance education.

Epsilon would not replace any existing teaching material, but rather provide an additional, alternative resource through which students might improve their basic skills and knowledge and addre ss any deficiencies. The software would give opportunities for independent learning, and attempt to cater for new learning styles: many students already spend more time working from a screen rather t han reading printed books.

The content of *Epsilon* was chosen to provide a comprehensive coverage of all the necessary topics in the many first year subjects offered at our multicampus university. *Epsilon* is organised in learning modules. The first stage, developed by Cristina Varsavsky and Ron Adlem, includes calculus topics. The second stage, developed by the authors, adds linear alge bra and introductory vector calculus. The finished product will include these modules:

1. Limits and continuity
2. Introduction to differentiation
3. Techniques of differentiation
4. Applications of differentiation
5. Introduction to integration
6. Techniques of integration
7. Applications of integration
8. Taylor approximations
9. Hyperbolic functions
10. Differential equations
11. Matrices
12. Determinants
13. The inverse of a matrix
14. Systems of linear equations

15. Applications of linear algebra
16. Vectors in three-dimensional space
17. Vector calculus
18. Eigenvalues and eigenvectors

3. INSTRUCTIONAL DESIGN IN *Epsilon*

The text and design have been specifically developed for *Epsilon*, and include several features. The aims of each module are clearly defined and appear at the beginning of it. Every module is d ivided into smaller units, each consisting of

(i) information pages
(ii) step-by-step worked example(s)
(iii) student exercise

The number of information pages has been kept to a minimum, making them as simple as possible while providing all necessary facts and ideas. Basic definitions and important conclusions are shown in c oloured boxes, while additional definitions, motivation, graphical illustrations, notation and proofs are disclosed via hotwords and click-on buttons. This is to suit the multiple purposes of the pro gram: students using it to revise may wish to focus on key information without having to flip through large numbers of pages; distance education students or those seeking a more detailed discussion m ight be more inclined to use the buttons and hotwords.

The page design was carefully considered: a compromise between the number of objects per screen and the time needed to display them had to be found, keeping in mind the authoring software and compute r standards. It has been found that a stand-alone version runs satisfactorily, whereas running the program through a network can make responses too slow.

The worked examples are presented step-by-step. At first only the question is shown. The user decides when to begin viewing the solution: this is also disclosed in stages. This should encourage activ e learning and investigation by the student.

A variety of styles has been used in the exercises, e.g. numerical answers, drag and match, true/false, multiple choice. The student's answer is immediately marked as right or wrong, and a fully work ed solution becomes available only **after** the user has offered an answer.

The design is intended to replicate the best features of good lecture presentation and skilful tutoring, and the directed conversation of a well-focussed mathematical discussion. The academics' exper ience with common student difficulties, and judgement of which key features need highlighting, underlies the provision of information and choice of questions; as it does in producing a printed textbo ok, a set of lectures, or tutorial problem sets. Gradual disclosure of a worked solution is an effective teaching method; in *Epsilon*, the student controls the pace.

Navigation through *Epsilon* is done using menus and navigation buttons. The main menu is followed by a menu for each module (to move to the units within it) and the usual navigation buttons are available. The natural, sequential structure of the electronic book can be followed using the *next page* button. In addition, the navigation bar provides access to a **toolbox**: a grapher, the calculator; some lists of useful formulae, integrals and derivatives; and on-line help. The grapher was developed i n-house to allow its free distribution with *Epsilon* to our students.

In the design of *Epsilon*, ample use of graphs, visual and audio presentation has been chosen. While

there are clear advantages for learning mathematics in linking conceptual, algebraic and vi sual aspects, it is also apparent that students arriving at university will have wider experience with graphing technologies and a greater inclination to think visually. There are also key points where animation is valuable and appealing.

4. EFFECTIVE PRESENTATION

"I have never understood why my mathematician colleagues sometimes seem to prefer precision over clarity" David S. Moore ([4])

How effective is computer based learning in mathematics? Time will tell. It seems evident that text must be pared down to a basic minimum. Since lengthy and formal (textbook-style) exposition has lit tle value in an electronic book, tight self-discipline is needed in writing. But this discipline can be valuable and rewarding for the writers; clarity and liveliness are the aims, supported by neat page design, good graphics, and opportunities for interaction. On the other hand, the studied informality, the friendly and chatty style of Ostebee & Zorn ([5]) for example, which works well in a printed textbook, might not be effective on screen .

5. DEVELOPMENT AND PRODUCTION

The *Epsilon* courseware was produced for the likely standard computer facilities in two years' time, using Windows as the platform and Toolbook CBT 5.0 authoring software. The program will be a vailable on CD Rom to all Monash mathematics students, and will be installed in the Mathematics Learning Centre ([6]) and on the university network.

The *Epsilon* template was carefully designed, in the light of guidelines given by instructional designers ([7] , [8]). The developers tested many interactive book s before deciding on the final template, to see what worked well, what is useful, and what can be confusing to the user. For *Epsilon*, the icons, navigation buttons, menus, and colour codes wer e chosen to create a pleasant appearance and give clear cues to make the electronic book easy to use and understand. Sample pages are shown in Figures 1, and 2.
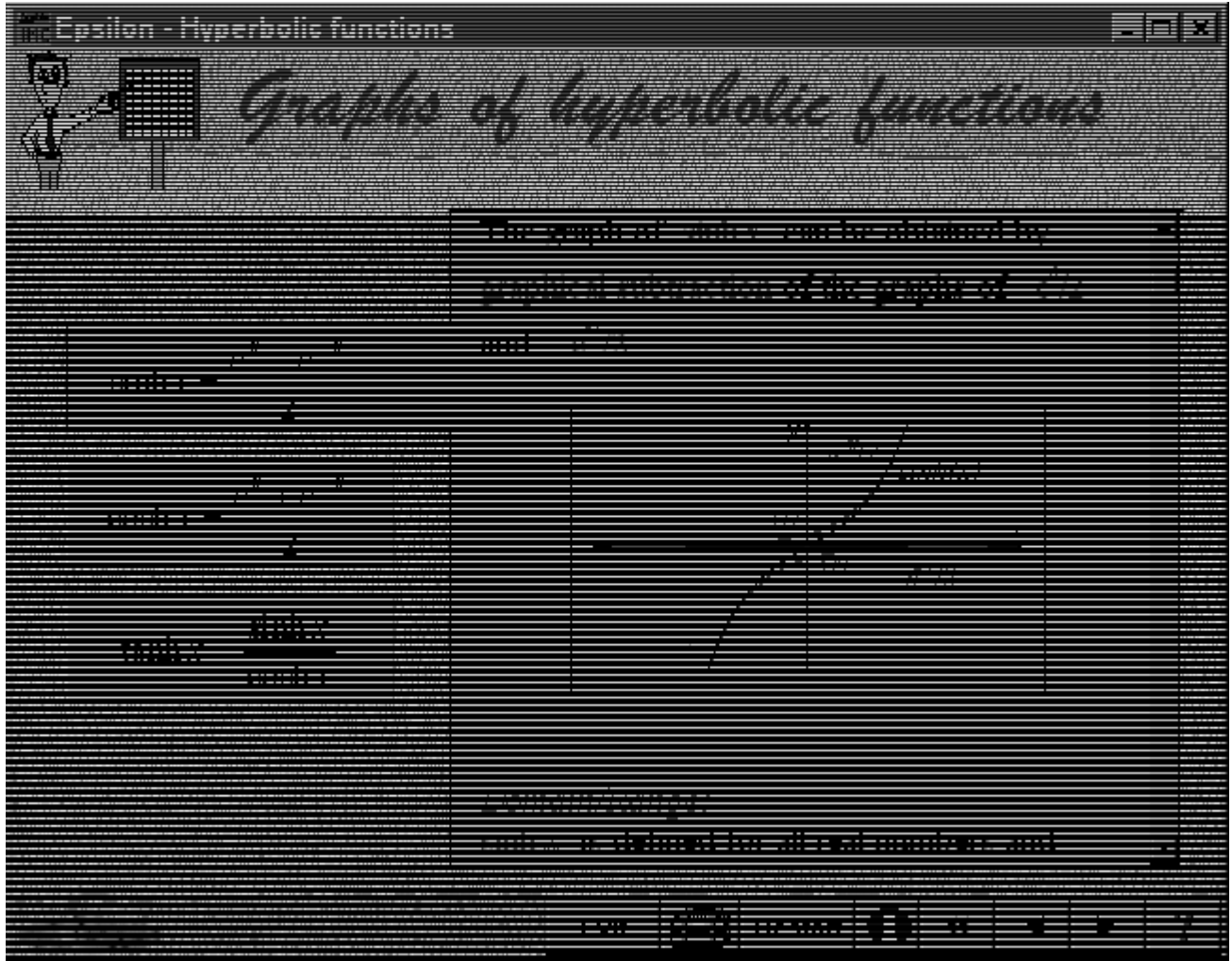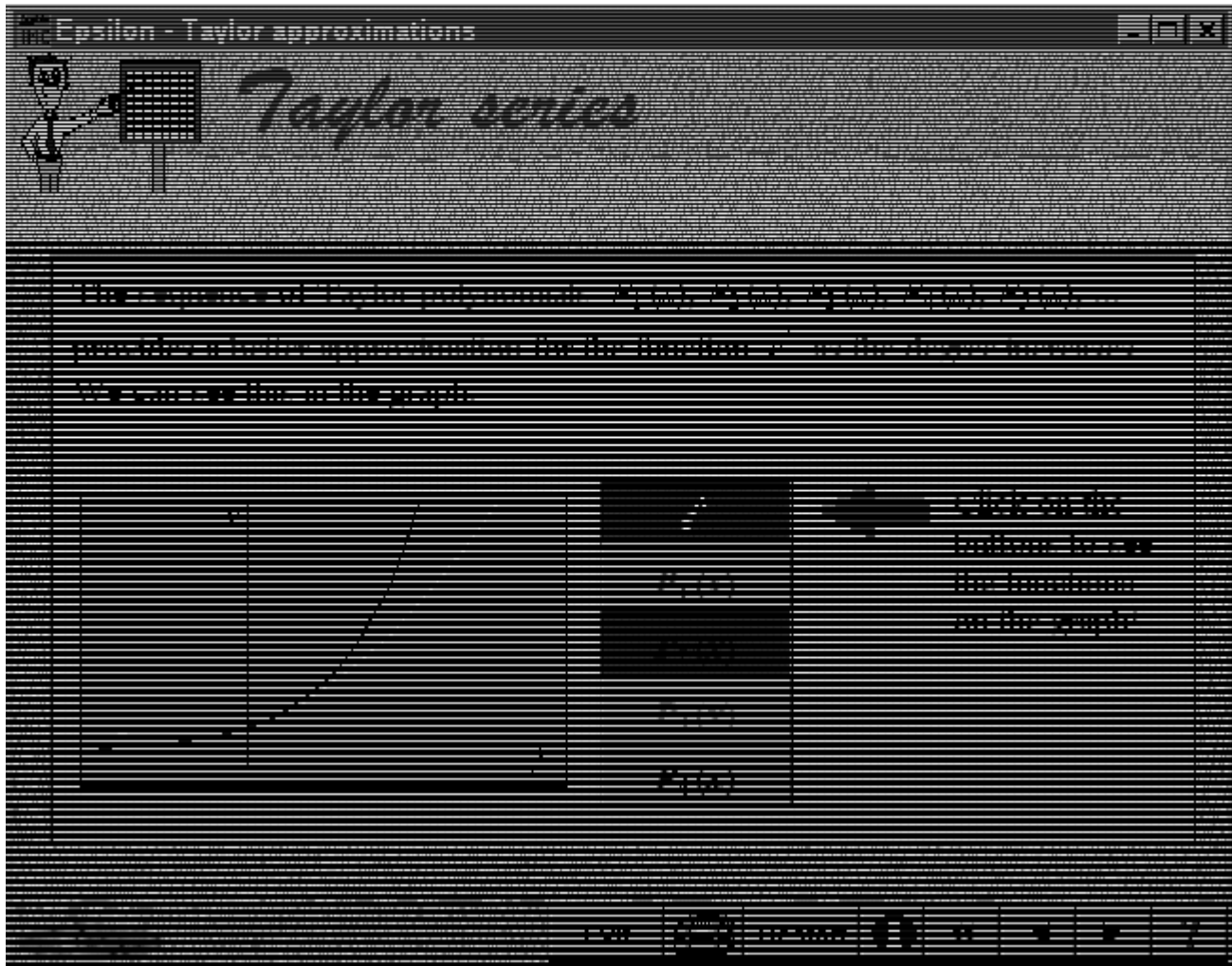
Figure 1

Figure 2

The textual material was written by the academics involved, and six months of a programmer's time were planned to implement the full electronic book. To improve efficiency, all material was typed in Word 6. The programmer then simply imported text and equations to Toolbook, enabling him to concentrate on the visual presentation, formatting, the graphs, the animations, the audio and video clips, and the programming itself. This procedure worked well, and was further refined by carefully proofreading and assessing the suitability of the material for display in electronic pages, since it was q uickly realised that it was easier and less costly to make changes in the word processor than in the electronic book.

Informal evaluations by students, teachers and an instructional designer were valuable early in the implementation process, and led to many changes. Formal evaluation and a final, full student evalua tion will also be used.

Toolbook is a sophisticated yet easy-to-use authoring system. But due to its origins in the business market, it has some limitations when applied to mathematics teaching. It is unable to display and evaluate the input of symbolic mathematical expressions, so our exercises had to be designed with that limitation in mind. Equations written in Word 6 had to be imported in bitmap format to be placed within text. This extended the programming task, but was manageable.

The *Epsilon* implementation process convinced us that a small, cohesive team, using a well-designed

template, can produce useful material for relatively modest costs. The often-expressed view, that production of clean and lively interactive multimedia for mathematics will always be far too expensive for most institutions, may soon be contradicted by counter-examples.

6. THE CHANGING FACE OF STUDY MATERIALS; CONCLUSION

Doubtless a wide variety of formats, styles, media and technologies will be used for fostering learning of mathematics, and most teachers already use many of these. In striving to support diverse lea rning styles, we are all too aware of the limitations of each.

- Traditional textbooks have many advantages; they are constantly evolving (magnificently designed coloured diagrams, accompanying software ...), and their good features are quietly borrowed for translation into other media. Attractive "case studies" [e.g. in Zill ([9])] can look like a video vignette.
- Distance education guides range from the startlingly brief and crisp to the high-fibre, wholemeal, unleavened doorstop.
- Tutorial problem sets can be good springboards for discussion, and provide hurdles that assist diagnosis of difficulties.
- WWW provision of materials needs more development, especially to overcome limitations concerning the use of symbolic expressions.
- Video at its best can perform wonders. The dissection of algebraic formulae in Against All Odds (COMAP) was inspiring; a film of Polya, Feynman, Erdos or Coxeter can be intriguing; the sheer beau ty of Powers of Ten or Arthur C. Clarke's Colours of Infinity may have a lasting impact.

Amongst all of these, interactive multimedia has a place that will consolidate, as its considerable potential is recognised. It can provide visually appealing material enhanced with animations, links to mathematical applications, graphical illustrations and interactivity, to be used as a self-paced learning resource for supplementing structured lectures and tutorials, and in distance education.

Epsilon furnishes our University with a new approach to teaching mathematics which takes advantage of computer software to shape the style and content of the material, while retaining the adva ntages of the traditional textbook format.

Effective use of existing authoring software and good planning can reduce the otherwise high costs of producing such materials. *Epsilon* provides an example of this.

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