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FEEDBACK AND ASSESSMENT IN AN OPEN LEARNING ENVIRONMENT

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The use of new information and communication technologies (ICT) has great potential for enriching learning. Styles of courseware are evolving and most include forms of self-assessment to guide the learner (formative assessment). There is however a link between formal assessment and the use of ICT based courseware to which insufficient attention has been paid: teachers and learners focus on examinations, but examinations bodies cannot use any but the simplest forms of ICT based assessment until learners are practised in their use. Members of the ITAL Unit are involved in several projects that address this impasse. Two mathematics projects, "Calculus Connections" and "Cambridge On-Line" are described in this context. Another project, TEEM, addresses the issues of best practice in the classroom use of new media.

Introduction

This paper will make observations relating to two recent major courseware[1] projects: "Calculus Connections" [1] and "Cambridge On-Line" [2], and discusses general issues concerning the use of such materials in education.

The potential for the use of new technologies in education was recognised from the earliest days of interactive computing. Even in the 1960's, when interaction was in practice limited to the typing and reading of text, several pioneering projects attempted to exploit the ability of a computer to adapt to the individual needs of learners. Such work was often associated with the theories of learning psychologists and the goal of achieving artificial intelligence (AI). Implicit in the concept of the computer-as-tutor is the idea that "the computer knows best". This ensured a sceptical attitude on the part of many in the teaching profession. This was probably justified although it appears that effective modern "integrated learning systems" (ILS) are being developed for specific curriculum areas. See "SuccessMaker" [3] for example.

In the 1980's the focus of attraction changed. The arrival of microcomputers and graphics displays at consumer prices encouraged an entirely different attitude. Here was a potential teaching tool under the control of the teacher. It did not supplant existing classroom methods but enlarged the repertoire, for example:

- Real-time graphing tools to enrich and enliven mathematics
- Simulations in sciences
- Multimedia resources for the humanities

These of course are only a few of the possibilities, and in more recent times we must include the use of Internet based resources.

The projects described in this paper belong firmly to the new era of educational computing. They should be evaluated by their usefulness to teachers as *part* of the

[1] The term "courseware" is commonly used to describe computer-based learning packages.

resources available to teach a subject. We shall call such packages "enrichment packages" in contrast to the ILS tradition.

Learning, feedback and assessment

Feedback and adaptive learning were the focus of much early work in computer-based learning, as noted. These are usually considered to be desirable characteristics and nearly all modern courseware has inherited them to some extent. This is usually at a very simple formative level such as self-test multiple-choice questions (MCQ) that the user is expected to answer at suitable intervals. More ambitious packages may include some degree of overall summative assessment.

There is however a link between courseware and assessment at a higher strategic level which becomes very plain when we consider the context in which teaching and learning are done. Pupils expect to be tested and examined. Schools and teachers are themselves assessed by their pupils' results. Both teachers and learners are therefore under pressure by the education system to teach and learn to the examination. Topics and skills that cannot be conveniently assessed under examination conditions are likely, to say the least, to be given less emphasis. This is where enrichment courseware has a major problem in present day education: its use does not obviously focus on the ultimate goal of passing examinations.

If we as educators are to exploit the potential of ICT based learning environments we must recognise the push-pull relation between learning and assessment:

- To test learners fairly using ICT based assessment, learners must have used ICT whilst learning
- To encourage the use of ICT in learning, examinations must include an ICT based component

It is left to the reader to decide which is "push" and which is "pull", but the two are clearly interlinked.

The ITAL Unit

The University of Cambridge is dedicated to the furtherance of learning and research, and the Local Examinations Syndicate (UCLES) naturally sees it as important to encourage the best educational practices. It has recognised that an examination body such as UCLES has a major part to play in the push-pull relation between learning and assessment, and has set up the ITAL Unit in response.

The aim of the ITAL Unit (Interactive Technologies in Assessment and Learning) is to carry out research and development into computer-based teaching and assessment, and to manage certain projects in this field.

Many significant strands in the work of the ITAL Unit have their origins in Cambridge University's Department of Applied Mathematics and Theoretical Physics (DAMTP). The first UK computer-based teaching project for undergraduate mathematics started there in 1969, known as CATAM (Computer-Aided Teaching of Applied Mathematics).

In the mid-1980's we formed a Research Group which we later called the "Interactive Courseware Research and Development Group" (ICRD Group). The ICRD Group has been in the forefront of developments in the use of computer technology in mathematical education and its work has won international recognition. As well as "Calculus Connections" (described below) projects in the last decade include:

- **The Computer Illustrated Text series (1983-90)** - these were amongst some of the earliest printed book-length teaching materials to be integrated with interactive computer software. Authors from more than 5 UK Universities were involved. They published 13 titles.
- **The Renaissance Project (1989-91) -** sponsored by Apple Computer UK. This was one of the first projects in the UK to develop hypertext courseware materials with multimedia.
- **The Mathwise Project (1992** -…) [4] sponsored by the UK Higher Education funding body. The ICRD Group played a leading role in the formation and development of Mathwise, a large scale collaborative project between over 40 academics in over 25 UK Universities, writing mathematical courseware to common standards and styles.
- **PASS Maths (1996-99)** - funded through a prestigious "BT University Development Award" (BT is British Telecom, the UK's largest telecom company), an Internet magazine devoted to promoting public understanding of mathematics.
- **Millennium Mathematics Project (MMP, 1999-)** The Faculty of Mathematics has raised funds for the Millennium Mathematics Project (MMP) to address public awareness of mathematics and provide a means by which the Faculty can contribute to the national and international development of mathematical education. It incorporates PASS Maths and is already beginning a range of new activities. The MMP is directed by Professor John Barrow.

Thanks to their links with DAMTP and earlier mathematics courseware projects, members of the ITAL Unit were well placed to support SNP Multimedia in the production of Cambridge On-Line.

New Technologies in Mathematics Learning

It is important to see the role of feedback and assessment in the context of the many ways that new technologies support mathematics. These many ways fall into four main groupings:

1) Simulation & calculation
   Examples: Maple, Mathematica; MathCad
2) Courseware
   Examples: Calculus Connections, Mathwise [4]
3) Public understanding
   Examples: Millennium Mathematics Project (MMP), Mathwright library [5]
4) Learning & Assessment
   Examples: TEEM [6], Cambridge On-Line

Any particular package, product or service relating to mathematics learning might well have characteristics linked to several of these. The TEEM project will be described below.

Before describing the two specific projects, here are some remarks intended to give a perspective on how these materials will fit into normal teaching. On account of the early "computer knows best" tradition (discussed above) some reviewers of computer-based packages find fault on the grounds of incompleteness. For a collection of resources designed to offer enrichment, incompleteness is not a fault it is a focus. This is because a computer-based approach may not be the best method to tackle a given topic, and so the package authors may fairly decide not to attempt to cover that topic. They will expect the teacher to select what the teacher judges to be the best method to teach any given topic, and this is what a good teacher will surely want to do in any case. A good enrichment package should be designed to be flexible, allowing the resources contained to be used in a variety of ways as the teacher (and also perhaps the learner) decides.

Courseware 1: Calculus Connections

Calculus Connections is a joint project between its authors and two US organisations, the publisher J. Wiley & Sons, and software house Intellipro Inc. Two volumes of Calculus Connections are published to date. Each is a CD-ROM multimedia package for PC/Windows, each having 8 modules plus a Laboratory Manual for each volume.

The package was designed as enrichment material and is not intended to replace the use of a standard text book. In fact it can be used with any existing course provided that some time is available for learning activities other than traditional "chalk and talk".

The consistent aim throughout the project has been to use the computer to do the things it does well (interaction, graphics, etc.), and avoid using it for things for which it is not best adapted (for example, delivering large amounts of text, especially mathematical text). In Calculus Connections we use multimedia to capture attention and set up real world situations in which mathematics can be applied. Then we use simulations and interactive graphics to explain how the mathematics can be applied to these situations. The overall intention is to motivate the student to see the *point* of studying maths, and to provide strong visual associations (mental coat-pegs) on which to hang recollections of the relevant theory. This is particularly aimed at those students who find mathematics unrelated to the real world at best and irrelevant at worst. To reinforce these learning opportunities, there is a printed Lab Book containing more mathematical details, with further explanations and exercises. Topics covered are as follows:

Volume 1:

1. Lines, Functions and Equations	5. Applied Maximums & Minimums
2. Limits	6. Areas as limits
3. Rates of change & differentiation	7. Fundamental Theorem of Calculus
4. Inverse & transcendental functions	8. Mean Value Theorem

Volume 2:

9. Definite Integrals	13. Differential Equations

10. Rectilinear Motion	14. Spherical and Polar Coordinates
11. Simpson's Rule	15. Parametric Equations
12. Sequences and Series	16. Mathematical Modeling

The material has been structured with short laboratory sessions in mind. For the student we have provided a simple structure of small blocks of material so that it is easy to navigate and intuitively simple to work out where to go and what to do next; however, the choice is left to the student. For the instructor we have made it easy to make assignments which encourage students of all abilities to explore calculus and its connections to the real world. The aim of the Lab book is to provide background mathematical theory, set exercises and more extensive problems.

Each module of Calculus Connections is built around two "real life" applications that are first presented to the student using multimedia technology. It is intended that the student will follow this by studying some key mathematical concepts, and then do some interactive exercises. A high level of interaction encourages the student to investigate the nature of mathematical models, and explore their relationship with the real world. The material is usually studied in that order, but the student can access any part of the package at will. Other resources include a 3-D graph plotter, glossary, mathematical biographies, on-line help about using the package, and links to computer algebra packages. There is an accompanying Laboratory manual which has more extensive textual material and extended exercises. This combination allows course instructors a great deal of freedom to exploit Calculus Connections to best advantage for their own students.

Courseware 2: Cambridge On-Line

Cambridge On-Line (COL) is a collaboration between SNP Multimedia Pte, based in Singapore, and Cambridge University Asia Pacific Training Services (CUAPTS). The ITAL Unit has supported CUAPTS in this work. COL Mathematics (COL-M) is an online learning service for students and adult learners studying mathematics at the level of the GCE ‘O’ and ‘AO’ examinations. In contrast to Calculus Connections the service is delivered entirely via the Internet.

Modes of Use

As you would expect from all web-based materials, COL-M is highly flexible and will be used in an enormous variety of ways. There are however two particular models of use which appear to best fit most likely users:

- Individual subscriber (eg use from home)
- School-based use

In school-based use, students have free access to COL-M from terminals located in rooms throughout the school. Individual subscribers have access from anywhere with an Internet connection. Every user has access to a performance tracking system, but for the school-based service COL-M allows mathematics teachers to track their students’ progress throughout the year. Teachers can pull out individual student records to determine where a student needs to direct more effort or do a cross-profile of class performance to ascertain classes that need extra lessons on a specific topic.

Contents of COL-M Site

COL-M was conceived as enrichment material. It does not replace normal teaching but acts in support. COL-M covers all topics in the GCE 'O' and 'AO' syllabuses. Materials available include:

- Interesting mathematics-related facts
- Animated tutorial modules
- Past year examination questions
- Additional challenging questions
- Syllabus information, updated as necessary
- Performance tracking data (as already mentioned)

The section on interesting facts emphasises real-life applications of mathematics and aims to show that mathematics plays a vital part in the modern world. The link with Cambridge's Millennium Mathematics Project provides further reinforcement in this respect, all aiding the motivation of students to study mathematics.

The tutorial modules are intended to reinforce initial teaching and are especially useful for revision. Practice is an essential and valuable part of learning, and COL-M provides access to a wealth of materials for this purpose. There is a large collection of past year examination questions. The student chooses a question (or may have been directed which to try by a teacher), reads the question on screen, then works out answers. Questions may be chosen by topic (for example, to revise "Equations and Inequalities") or by year and paper. If help is needed at this stage then a range of hints is available. Answers are then typed in and submitted to COL-M for checking. The system then displays a worked answer and tells the student whether the student's answer was correct or not.

To encourage a wider perspective and promote thinking skills, challenging questions are there to ensure that study does not become routine. Challenging questions are accessed in exactly the same way as past year questions.

Role of the ITAL Unit

SNP Multimedia Pte is the designer and developer of COL-M. The ITAL Unit on behalf of CUAPTS has supported their work through advice and constructive comment on design and interface issues. The ITAL Unit also arranged for the writing of new questions, the writing of all worked answers, and the checking of the finished materials.

Sample materials

Figures 1, 2 and 3 give a glimpse of the COL-M site. Figure 1 shows a question with answer boxes waiting to be completed. In this case the answers expected are numeric, but in other cases algebraic answers are supported too. Figure 2 shows the display after the user has clicked "Submit". Figure 3 shows part of a challenging question and also illustrates the use of diagrams in questions and answers.

TEEM: Teachers Evaluating Educational Multimedia

In the introduction to this paper, it was stressed that 'new era' courseware should be seen as enrichment material. This raises the question of how best to use such resources in the real classroom situation, a question that many practising teachers may

feel has been neglected in the past. The ITAL Unit is therefore supporting an initiative known as TEEM (Teachers Evaluating Educational Multimedia) [6]. TEEM is also sponsored by the DfEE (UK education ministry), The Guardian newspaper and BESA (British Educational Suppliers Association).

The TEEM project publishes a web site containing a collection of evaluations and examples of classroom use of a wide range of multimedia resources currently available to schools. Most of these resources are published on CD ROM, but some are on Web sites. Evaluations and examples of use, called case studies, have been produced by working teachers after using the resources in their school. These teachers are trained TEEM Evaluators. They use the TEEM frameworks to help them write their evaluations and case studies. Each resource is evaluated separately for each Key Stage the publisher has proposed as suitable. In addition, the publisher produces detailed information about what each resource has to offer.

Evaluations and case studies place a particular emphasis on what the objectives were in using the resource, and how it contributed to and enhanced the learning that resulted. These case studies are designed to inform teachers, in training and practising, on the effective management of these resources in their teaching.

TEEM evaluators are all working teachers, from all over the UK. All school subjects are covered.

In the pilot phase to January 1999:

- frameworks for evaluation were established
- 60 teachers were trained in evaluation
- 35 publishers were recruited
- 80 titles were submitted for evaluation
- a web site was established for access to the resulting databases, and this was accepted as part of the National Grid for Learning.

TEEM has received further substantial sponsorship from the DfEE and is now setting a programme for the next 3 years. It is planned to produce approximately 1000 evaluations per year covering topics for all of primary and secondary education.

Conclusion

Computer-based learning is clearly set to play an increasingly important role in education. The roles of computer-based learning and computer-based assessment are closely linked and progress in one depends on progress in the other. Support is also needed for teachers and lecturers as they learn how to take advantage of both roles. UCLES is ready to play its part to assist and encourage every part of this process, and our collaboration with SNP Multimedia Pte in the production of Cambridge On-Line Mathematics is a leading example of our activities.

Cambridge On-Line Mathematics itself is an enrichment resource that spans both traditional paper-based teaching and assessment, and is also leading the way towards the use of newer ICT-based methods. This project and related activities will help teachers and learners to take full advantage of the opportunities that new technology brings.

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