Progressive Teaching of Mathematics with Tablet Technology

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Abstract

We investigate a multimodal approach to lecture presentation built on tablet technology. This innovative approach presents a framework which provides organizational structure to the lecture and facilitates incorporation of additional detail through electronic ink. Diagrams, solutions and concept maps are developed spontaneously in real time, thus engaging and promoting student directed learning, through a creative, interactive and dynamic process. Our study analyzes benefits and drawbacks of this approach, through evaluation of instructor experiences and student feedback for three undergraduate mathematics courses held over three consecutive semesters.

Keywords: Tablet, undergraduate, multimodal, electronic ink

Introduction

Non-interactive computer technologies, such as PowerPoint slides, are standard tools used in modern lectures, yet, if slides are prepared entirely before delivery, we must question the effectiveness of these methods for the cognition of mathematical concepts. Such formats limit flexibility and encourage passive learning, and do not engage students since lectures cannot be adjusted based on audience reaction.

In response to this perceived problem the authors have investigated a multimodal approach to lecture presentation built on tablet technology. This new technology promotes a dynamic and interactive learning environment which fully engages students.

This paper reports on results of a study into teaching tertiary undergraduate mathematics using tablet technology and presents an analysis of students' responses to this multimodal approach. Data has been acquired from students taking three different mathematics courses in three consecutive semesters; two of these courses were first year classes and one a second year class.

Lecturers' experiences of this technology are discussed and implementation issues including benefits and difficulties are analyzed. Benefits of tablet technology can include high quality output, enhancing the ability to store and cross reference all presented material. Electronic ink notes can readily be posted on a website, providing easy access for on campus and distance students. Problem solving techniques can be demonstrated and cognition is enhanced by reading, listening, writing and thinking during a lecture.

Related work

Students need to learn mathematical symbols as well as mathematical explanation (Lowerison et al., 2006; Townsley, 2002); they need careful step by step instruction on how to work through a problem and how to present a solution in clear and precise, mathematical language (Loch, 2005). Consequently, real time delivery of problems and their solutions is an important aspect of any mathematics lecture.

The usefulness of electronic ink for lecture delivery has been discussed in a number of educational research papers. While some authors use a Tablet PC (Simon et al., 2003), others describe experiences with considerably cheaper graphics tablets (Loch, 2005; Loomes et al., 2002). Software packages have been written to perform certain tasks, many of which are tailored for distance education.

One example is Classroom Presenter, developed by Simon et al. (2003) in collaboration with Microsoft Research. Classroom Presenter is used widely in the US tertiary teaching sector, and is available for free download from the authors' website. PowerPoint presentations are delivered in Classroom Presenter, which offers the potential to add space for live handwritten material. Classroom Presenter was first tested for computer science courses, then taken up by other disciplines such as engineering (Anderson et al., 2005). Its distinguishing feature is the use of the projector as an extended desktop, where the computer screen displays an instructor version of the presentation, including slide overview and personal comments which may differ from the projected image.

Recent releases of MS PowerPoint offer a pen mode, which allows adding ink to a slide during presentation. This feature can only be used to its full potential if a Tablet PC with Windows XP Tablet Edition is available, or if at least the latest version of MS Office is installed, since handwritten material may be lost during slide transition otherwise. However, as Microsoft Equation Editor is sometimes awkward to handle, PowerPoint presentations using electronic ink are more useful for courses which do not involve many typed mathematical formulae.

While it is clear that the concept of using electronic ink for lecture delivery is not new, our approach differs from previous approaches because it is compatible with mathematical typesetting in a natural way and is more suitable for demonstrating mathematical formulae than PowerPoint based ink approaches.

Background and Implementation

The Department of Mathematics at the University of Queensland developed lecture workbooks for all first and some second year courses (see Donovan (2000) for example). These workbooks contain background material, but also include blank boxes for addition, during lectures, of proofs, worked examples and student comments. The workbooks are written in LaTeX, a mathematical typesetting language, and offered as high-quality PDF files for download.

Apart from its portability, an advantage of the PDF format is that it can be used for dynamic lecture presentations, run in Adobe Acrobat Standard and allows for the adding of comments, which may be typed, pasted as images, imported from a file or written as electronic ink anywhere on a page. These comments can be saved separate or merged with the original document.

During a lecture, the PDF file can be projected on the screen, giving organizational structure to the lecture and a framework which supports subsequent discussions. Missing as well as extra detail can be added with electronic ink. Solutions to problems may be developed spontaneously in real time thus promoting student directed learning and creating an interactive and dynamic learning process which fully engages students.

Environment

In our study, we experimented with tablet technology and the PDF workbook for teaching three different courses over three consecutive semesters, all offered to on campus students only. Two of these courses are first year courses, and one a second year course. Details are as follows:

- Course 1 – semester 2, 2004 – Calculus and Linear Algebra I – taken by about 320 Engineering and Science students.
- Course 2 – semester 1, 2005 – Calculus and Linear Algebra II – taken by about 600 Engineering and Science students.
- Course 3 – semester 2, 2005 – Discrete Mathematics – taken by about 120 IT, Science and Electrical Engineering students.

While for courses 1 and 2 a graphics tablet was used, a Tablet PC was available for course 3. Course 1 was taught completely by one of the authors, while the other author taught the linear algebra component of course 2, as well as the logic and proof sections of course 3. The remainder of course 2 and 3 was taught by different lecturers, using traditional printed overhead slides.

Feedback and results

Towards the end of the semester, students in all three courses were asked to fill out a survey form. Some of the questions were the same for all three courses, while others were tailored to the specific situation. The contexts and results are presented as follows; an overview of answer distribution for similar questions can be found in Table 1.

Question	Course 1	Course 2	Course 3
I prefer if lecturer writes on computer	80%	12%	24%
I prefer if lecturer writes on OHP	3%	60%	42%
Writing during lectures helps my understanding	89%	65%	95%
I cannot read lecturer's writing	12%	38%	11%
I can decipher/it is easy to read	79%	30%	71%

Table 1: Distribution of answers for similar questions for all three courses

In the first week of the semester, lectures in course 1 were presented with Acrobat Reader on the computer, with additional/missing material written on OHP (overhead projector). Due to too little projection space, the OHP was difficult to see. Computer-only projection, and writing with the graphics tablet, was introduced from week 2. No major technical problems occurred from this point onwards. Out of 65 students who responded, about 85% said they preferred writing in the workbook during lectures to receiving a complete workbook. Nearly 89% thought that writing helped their understanding. Asked if they preferred if the lecturer wrote on the computer, 80% agreed, while 3% responded that they preferred lecture presentation with an OHP. More than three quarters (79%) responded that they could decipher the lecturer's writing. The completed lecture material, with all additions, was made available on the course website shortly after each lecture. Furthermore, 92% responded that they were in favour of computer-generated lecture notes being available on the website. About 46% said they knew students who "never go to lectures because the material is on the web" (see also Loch (2005)).

The linear algebra component of course 2 was taught entirely with an A3 size graphics tablet. This tablet was more difficult to handle (and carry) than a smaller tablet used in course 1 (A6 size) and the lecturer encountered a number of technical difficulties with the software. While all materials were available on the web, annotated notes from lectures were not. Out of 160 students, 65% agreed that additional comments, written during lectures enhanced their understanding of the course material. Only 30% of students said they could read the lecturer's writing easily. Keeping in mind that students had a direct comparison with OHP from the calculus component, 12% preferred writing on the computer as mode of presentation while 60% preferred OHP.

Course 3 was taught with a Tablet PC. Although some technical problems occurred, they were quickly fixed and did not eat into lecture time. Base lecture notes, but not annotations, were made available on the web. Out of 38 student responses, 95% agreed that examples written during lectures enhanced their understanding. 71% said they could read the lecturer's writing easily, and 42% thought the lecturer appeared to be comfortable with the technology. A surprisingly large number of students responded that they prefer the blackboard as mode of presentation (31%), up from 2% in course 2, while 24% said they prefer writing on the PC and 42% writing on the OHP.

A focus group of two students both enrolled in course 2 and 3 were interviewed to establish why students' perception of tablet technology had changed from course 2 to 3. They responded that the graphics tablet in course 2 was too big and difficult to handle and they preferred the Tablet PC, but acknowledged that the differences in technologies were not related to course material. The lecturer was more confident with the technology in course 3, and set up time was shorter. The writing on the Tablet PC in course 3 was easier to read and understand, while the graphics tablet in course 2 created a distraction. The focus group said that "everyone was frustrated" in course 2. This was not the case in course 3. However, the two students found that from the side of the lecture theatre it was difficult to read the OHP projection of the calculus component in course 2. Somehow, material seemed to be covered more quickly with the tablet, and the lecture appeared more organized compared to OHP. Asked if they thought that tablet technology is just another teaching tool or if it improved their learning, they agreed with the latter responding that material presented on Tablet PC was easier to understand compared to that presented on OHP.

Discussion

After trialing tablet technology together with lecture workbooks for three semesters, we believe that - despite initial set backs - this technology is a useful tool for the modern mathematics lecture. It combines computer-generated slides and activities with handwriting to emphasize key concepts or to facilitate modifying a path to a problem solution in response to student questions. Students can actively contribute to the lecture and may find their question or answer recorded on the lecture slide. Students appreciate that the lecture material is given to them in the form of the workbook, which provides writing space and organization of the material in one location.

Survey results and student comments suggest that the lecturer's competency and dexterity with the tablet is a key factor in the successful teaching with this tool. Any benefits of tablet technology such as being able to refer back to previous material, keeping an exact high quality copy of lecture material and being able to post on a website were outweighed by technical issues in course 2. As stated by Anderson et al. (2005), "a risk inherent in using new technology in the classroom is that the technology becomes a distraction rather than a complement". The enormous size of the graphics tablet used in course 2 was one of the reasons contributing to frustration in students and lecturer.

While the Tablet PC is more versatile, easier to use (writing takes place on the screen and requires less hand-eye coordination) and allows additional features, the use of the graphics tablet was very well received in course 1.

Writing on a graphics tablet/Tablet PC is not difficult. In fact, Anderson et al. (2005) address legibility, layout, colour and contrast, periodically cleaning up a slide, pacing and space for inking and student note-taking. This advice would apply equivalently to writing on overhead slides.

The seriousness of technical problems and reliability of the equipment are major factors impacting on the successful use of tablet technology. In course 1, OHP technology together with computer projection appeared to be useless due to a lack of projection space, while this problem did not exist in courses 2 and 3. Students were able to directly compare tablet and OHP based teaching in course 2, and preferred the more familiar (and reliable) overhead approach. Their attitude was very negative towards tablet technology as they thought it was wasting valuable teaching time. This was clearly reflected in survey responses. Interestingly this attitude improved as the lecturer's competency with the technology improved.

Students were able to download lecture material with electronic ink notes in course 1, which made the handwriting feature important as they were not told that full typed solutions existed.

Conclusion

The current study investigates an alternate multimodal approach built on tablet technology and electronic ink. This innovative approach proposes a framework compatible to mathematical typesetting which supports subsequent discussions and provides organizational structure to the lecture. Additional detail is incorporated through technologies, such as electronic ink. Diagrams, concept maps and solutions are developed spontaneously in real time thus promoting student directed learning and creating an interactive and dynamic learning process which fully engages students. As the material is developed spontaneously it ensures a flexible process, building on student's abilities. Tablet technology facilitates backtracking, the redefinition of ideas, the refinement of solutions and the investigation of alternate paths. It allows for the conceptualization and comprehensive understanding of complex mathematical ideas. Students are not overwhelmed by impenetrable solutions but may interact with the development process.

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