Tablet Technology in First Year Calculus and Linear Algebra Teaching

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Abstract

Although tablet technology has been around for more than a decade, it seems to be used mainly in niche markets such as arts and design, and it appears to have bypassed most of academia.
The purpose of this paper is to show the usefulness and effectiveness of tablet technology in undergraduate mathematics teaching by sharing experiences made using a graphics tablet for lecturing a large first year class. It is meant to encourage discussion of current teaching tools, for instance for lecture delivery, preparation of on-line material and student consultation at a distance. This technology allows writing by hand on the computer as well as keeping a record of what has been written, which makes publication of this material on the course website very simple.

Keywords
Tablet technology; large first year class; Tablet PC; graphics tablet; pen-based lecture delivery; workbook

AMS Subject Classification:

1. Introduction

Mathematics lectures have traditionally been presented on blackboards. As Townsley [9] points out, "*One reason we all use blackboards to write down mathematics is the symbols with which mathematics is communicated. Writing the symbols down gives the student a chance to read what has been spoken and thus access the content via several senses*." Apart from mathematical symbols, students also need to be shown step by step how to work out a problem, and how to write down a solution in a clear and precise, mathematically correct way. Students need to learn mathematical explanation [4].

Nowadays, the blackboard is often replaced by overhead projectors (OHPs). The advantage of this is that the lecturer can refer back to what was written earlier, and may be able to keep a record. It is possible to cover more material faster, as lecture notes can be prepared in advance, printed or written onto slides and presented more quickly in the lecture.

In the last decade, computers have found their way into the classroom, as presentation software has become more user friendly and easier to use. However, programs like PowerPoint used on a standard computer are non-interactive tools [10], where the lecturer shows one slide after the other, maybe revealing one line at a time. In an interactive learning atmosphere, students see how the lecturer develops a solution from scratch and they can contribute to a particular path. This is lost when everything is typed before the lecture begins. One popular way to overcome this is the combination of computer-based notes and OHPs or blackboards. The lecturer displays the theory on the computer, and evolves proofs or worked examples separately by writing on the other medium. While this method enables interactivity and allows covering more material, no electronic copy is kept of what was written during the lecture.

There is affordable hardware and software technology available now that allows direct hand-writing on the computer, and saves a copy for later reference or for posting on a website. This technology is the graphics tablet, or, more expensively (and sophisticated), the Tablet PC, in combination with software that allows annotating of text or simply drawing. To date, few Tablet PCs have been sold in academia [10], and even fewer universities seem to have introduced tablets into mathematics teaching. A notable exception is the University of Colorado, where for a range of courses both voice and image are recorded and presented to external students via MathOnline [1]. Another promising tool, used to tape lectures before publication on the web to external students is Audiograph [4]. This multimodal software [7] records voice as well as pen movement and is used with an emphasis on teaching mathematical explanation [4]. Both of the above use speech and pen recording for teaching external (distance) students.

In this paper, I will describe my experiences using a graphics tablet for lecturing a large first year mathematics class of internal students, by writing in the electronic lecture workbook during class. Advantages and disadvantages will be mentioned, student perception will be described and an outlook will be given into the potential of such technology for teaching both internal and external students.

I would like to emphasize that this paper presents a survey of current methodology and a report of the initial exploration of the usefulness and advantage of tablet technology in course delivery. It is meant to encourage others to consider this technology for their teaching setup and make them aware of its potential.

2. Graphics Tablet Technology and Adobe Acrobat (Standard)

1.1 Brief History of Graphics Tablet and Tablet PC

Graphics tablet technology has been around for a number of years, with the first tablet input device introduced by Wacom [11] in 1988. These days tablets are available in various sizes, where bigger is not necessarily better, as many people prefer a smaller tablet to minimize arm motion [2]. Tablets usually connect to the USB port and are powered by the computer.

Tablet PC's were first offered in the early 1990s. In 2002, Microsoft introduced a specialized Tablet PC operating system, Windows XP Tablet Edition, which is a full version of Windows XP Professional with tablet specific additions such as handwriting recognition. Both have been used mainly in niche markets such as manufacturing, graphics arts and design. They have not yet found widespread acceptance for university teaching. A very informative online overview of tablet technology can be found in [3]. It concentrates on Tablet PCs and their use in education, and gives reviews and results of trials. Detailed information about graphics tablets is given in [2].

3. Tablet technology in teaching first year mathematics

1.2 Course specifications

Calculus and Linear Algebra I (MATH1051) is the first mathematics course taught at university level, offered to internal students twice a year at the University of Queensland. Students are enrolled in programs such as Engineering and Sciences, and this course is usually compulsory for their studies. About 500 students enrol in semester 1 (taught in two streams), and 300 in semester 2. Every student attends three hours of lectures a week, one tutorial hour and one practical class (Matlab based).

In semester 1, 2004, the lecture notes were available for the first time electronically in the form of a workbook (PDF format, also for sale in print at the bookshop), which contains the relevant material and includes a large number of blank boxes (see Appendix B for an example page). Students fill in these boxes during lectures. Material to be filled in can be a theorem, a proof, part of a proof, a definition, or an example. The boxes are distributed with the intention that a lot of material can be covered quickly, but at the same time allowing enough time to be spent solving interesting examples in detail by writing out the steps, or defining and explaining new and important concepts.

In addition to the student version of the workbook, there is also an instructor version, where the blank boxes are filled with the relevant material in type. The introduction of the workbook has made it easier for lecturers new to this course to see what is covered, and to prepare for lectures. It has lead to a standardized way of presenting the material. Since the introduction of the workbook, MATH1051 has been taught by presenting the student version of the workbook on the computer projector and writing solutions by hand on blank transparencies, or by displaying workbook and solutions on the computer, where typed solutions were revealed one line at a time.

In recent years students have begun to ask for complete lecture material to be posted on the web following the lecture, to allow them to compare notes or to catch up on missed lectures. Either the completely typed solutions or scans of transparencies were published on the course website.

1.3 Why use graphics tablet technology?

When I took over lecturing of MATH1051 in semester 2, 2004, I decided to fill in the blank boxes of the workbook by writing in the lecture. I believe that it is important not only for students to see how the solution of a mathematical problem evolves by writing out each step by hand, but that it also increases my own motivation and engagement for the course. Students are required to set-out their solution by hand in assignments and exams, and will benefit from seeing the lecturer "work out a problem". It can be tiring to sit passively in a lecture, and I admit that I tend to go faster than intended if there is nothing to write. Hand-writing is more dynamic and thus gives the flexibility to draw additional graphs, explain concepts further, show alternative methods of solving a problem or pose additional problems, for example when answering student questions.

In the first few lectures of the semester, I attempted to project the workbook onto the screen and wrote the contents of the boxes on transparencies. I encountered unexpected difficulties, as recent refurbishment left the lecture theatre without sufficient wall space to use computer and overhead projector simultaneously. As soon as the computer projector was turned on, a large screen was lowered from the ceiling, covering any other available wall space. The computer projection was conveniently centred on the screen, leaving about half the necessary space on either side for an overhead projection. My decision to change the method of lecture delivery was also driven by the brightness of the OHP. I found it impossible to keep eye contact with the students because my eyes did not adjust quickly enough and I simply could not see them in the relative darkness of the lecture theatre.

1.4 Experiences made using a graphics tablet

I decided to try a very small graphics tablet (about $100) for writing directly on the computer, in combination with Adobe Acrobat Standard. Since the workbook is available in pdf format (converted from LaTeX), this seemed to be the obvious choice. Acrobat Standard is an elegant solution as it incorporates a commenting function that allows one to hand-write on an existing pdf file, as well as to include images such as Matlab graphs. Comments are objects that can be added on top of the underlying document without changing it, and they can be edited until the document is printed to a file. This file is then readable by Acrobat Reader, a program available free of charge for all operating systems. Comments may be written in various colours, for example to point out changes or additions made after the lecture.

Although writing on a tablet requires a certain level of hand-eye coordination, as the user writes blindly on the tablet while looking up at the screen, I found it did not take long to get used to writing with the pen, both standing in front of the class and sitting at my desk. I was in fact so impressed by the ease of use of both the pen and the software, that I began exploring further use such as keeping a record of the material to be posted on the website, where students were able to view an exact copy of what I had presented. Preparing material for the website took no more than five minutes, and this includes improving my handwriting in places where I thought it was difficult to decipher because I had written too fast. I quickly found other areas where pen-writing proved to be helpful,

such as posting additional handwritten notes on the website to further explain topics students found difficult to understand. I found it easy to reply to student questions with an image or pdf file attachment containing the solution in hand-writing. Writing on the tablet saved a lot of time, as I no longer needed to type notes in LaTeX.

One may argue that posting lecture notes on the website will decrease student attendance. I had the impression that students regarded the web material as a very helpful addition to, rather than a replacement of lectures. During my experiences with MATH1051, I claim that posting lectures on the web had no effect on attendance, which is an observation that was shared in [5] and [1].

After getting used to the tablet I was able to borrow a tablet PC for a few lectures. Tablet PCs are quite expensive compared to graphics tablets that connect to existing computers. However, they offer the advantage that the user can see pen movement while writing, as writing takes place on the screen. Overall, the tablet PC seemed to be even easier to use than a tablet, and it requires less space since the writing surface is integrated.

1.5 Student Perception

Graphics tablets had never before been used to lecture in mathematics at the university. Students were asked for feedback on the workbook, writing on the computer and the course website where lecture material was posted after the lecture. Out of the 65 participating students,

- 89% agreed that “writing during lectures helps my understanding”
- 80% said they prefer if the lecturer writes on the computer (12% didn’t care)
- 92% agreed that “it’s great to have computer-generated lecture notes on the website”

Students were also asked to write comments about the course set-up. Some of these comments can be found in Appendix A. Overall, students seemed to like the graphics tablet, and it was much preferred to the OHP. Students noted that the computer projection was easier to see than the overhead projection. They found the website very helpful, as they could download lecture notes whenever they liked.

This student survey was meant to give immediate feedback on a new teaching tool half-way through the semester. It does not give an accurate view of how students judge effectiveness of the use of this technology. I agree with Lowerison [5] that it is possible that the technology used may be perceived as a means to deliver the material and not as a means to promote learning.

4. Conclusions and potential of this technology

The graphics tablet is an affordable and efficient teaching tool that is very easy to use. It was preferred to the OHP by most students. I have got used to it in such a way that I would not want to have to teach this course without. I believe it replaces the need for blackboards and OHPs completely, while still allowing hand-writing of mathematics. Although writing takes place on the stationary tablet, the lecturer does not need to remain

in one spot for the whole time. I found it natural to walk between the computer and the screen to further explain concepts, which kept the lecture dynamic.

New technology is often used in the same way old technology was used, and not to its full potential, because of lack of knowledge and comfort of familiarity on the user's part. Tablet technology should not simply replace the need for an OHP. Its advantages need to be identified and appropriately used, for example the advantage that notes written on the computer can be saved and published on a course website, without the need to use a scanner. With Adobe Acrobat Standard, notes can be saved directly in Acrobat Reader readable pdf format. Tablet technology can also be useful when answering student questions by email or in discussion groups, as an image can be attached that contains the worked out solution step by step. Additional information, complementing the lectures, can easily be posted for download on the website. The amount of time saved by not typing in LaTeX is enormous.

There is huge potential for tablet technology in distance education. McCloskey wrote that tablet PCs "*should be a boon for distance educators who will be able to mark up electronically submitted papers with Ink and e-mail the hand-notated assignments back to students*" [6].

Some discussion group software allows the use of whiteboard space. An instructor's writing could be read in real time by students who are signed-on. However, the full potential of this application would only be used if both sides, instructor and students, were using graphics tablets. Graphics tablet are now available for less than AUD 100, and "*it may become appropriate to require students at a distance to purchase such devices in order to better interact with the instructor*" [6].

Literature on the effectiveness of tablet technology for mathematics teaching appears to be scarce. A comparison of the various software applications suitable for handling hand-written mathematics needs to be performed. Only Adobe Acrobat Standard was explored in this paper, as the course material had been prepared in LaTeX and conversion from LaTeX to pdf is natural. It presented a fast and reliable way of writing in lectures which had to be found because of shortcomings in lecture theatre equipment. Better and cheaper software may exist, and may be in use elsewhere.

5. Acknowledgements

I would like to thank Michael Bulmer for purchasing the graphics tablet from his teaching funds and for generously lending it to me for the whole of the semester. I would also like to thank Phil Pollett, for allowing me to try his Tablet PC for a few lectures.
The explorations of tablet technology took place while I was appointed as a temporary lecturer at the University of Queensland.

6. Appendix A

The following is a selection of comments made by students on the survey form.

1.6 Writing in lectures

- Perfect lecture set up. Perfect course for that matter, I've really enjoyed this subject, each maths subject should have this setup
- Keeps me awake in lectures
- Writing assists with comprehension
- We work through problems together
- It is an incentive to come to lectures, you can learn more by writing it down
- It makes the lecture more active, rather than passive listening
- The lecturer's writing is easy to understand
- It's easy to see how the concepts are applied. Shows how to set out problems/working
- Allows you to concentrate a bit more on what is being said instead of copying notes down all lecture
- The graphics pad is easier to see than the OHP
- Good to see use of technology in a lecture theatre!
- The computer is heaps better than overheads
- Love the graphics pad! Very useful and modern, 1000x better than OHT
- I can't follow along when writing. I have to go back to read them later to understand
- Though the lectures are better on the computer they would be easier to understand if they were typed up
- Computer-written notes are sufficiently easy to read, but not best for proofs

1.7 Availability of notes on the course website

- I know exactly what I miss in lectures (if I miss them)
- The writing on graphics tablet is fine, especially as can get it of net easily
- It's good to make sure what you wrote down is correct on the website. I doubt that people who don't come to the lectures can understand from just the material on the web
- Very useful if you miss a lecture
- It's really helpful
- Website is essential
- Able to catch up on notes

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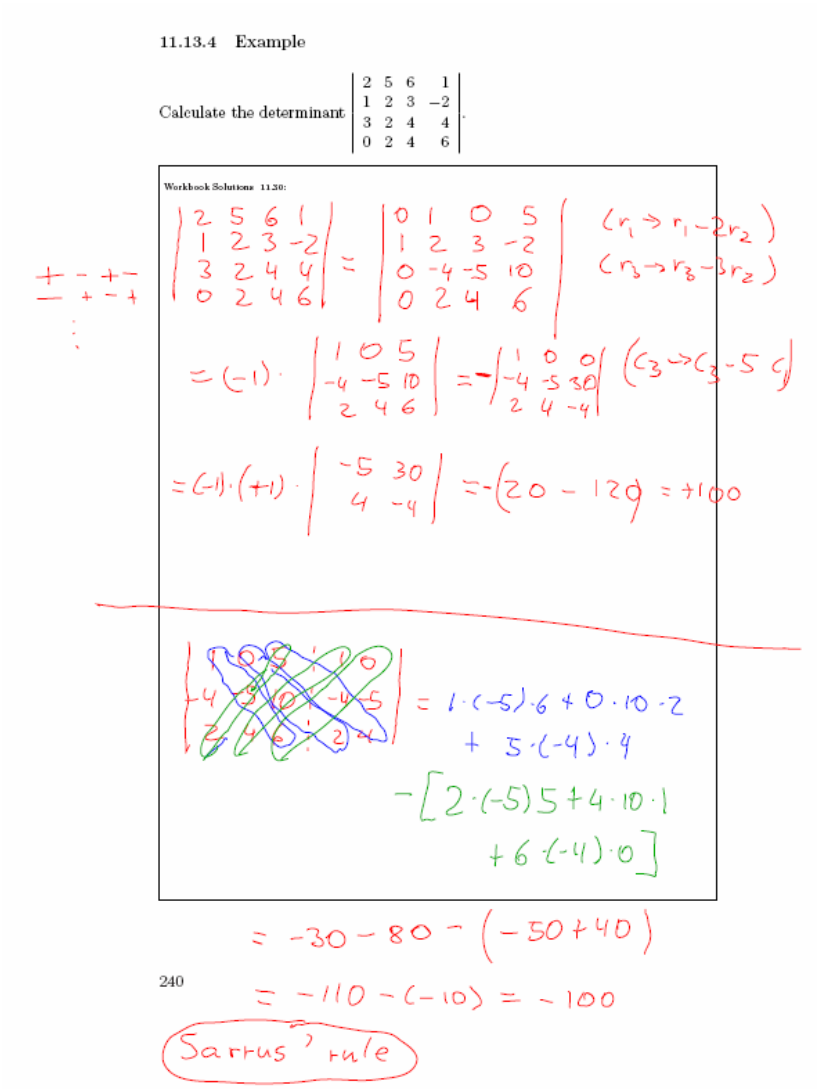
7. Appendix B

This is an extract from the lecture notes published on the course website. Sarrus' Rule was not covered in the lecture material and was briefly introduced for this example as an alternative method.



11.13.4 Example

Calculate the determinant $\begin{vmatrix} 2 & 5 & 6 & 1 \\ 1 & 2 & 3 & -2 \\ 3 & 2 & 4 & 4 \\ 0 & 2 & 4 & 6 \end{vmatrix}$.

Workbook Solutions 11.20:

$\begin{vmatrix} 2 & 5 & 6 & 1 \\ 1 & 2 & 3 & -2 \\ 3 & 2 & 4 & 4 \\ 0 & 2 & 4 & 6 \end{vmatrix} = \begin{vmatrix} 0 & 1 & 0 & 5 \\ 1 & 2 & 3 & -2 \\ 0 & -4 & -5 & 10 \\ 0 & 2 & 4 & 6 \end{vmatrix}$ $(r_1 \to r_1 - 2r_2)$ $(r_3 \to r_3 - 3r_2)$

$= (-1) \cdot \begin{vmatrix} 1 & 0 & 5 \\ -4 & -5 & 10 \\ 2 & 4 & 6 \end{vmatrix} = -\begin{vmatrix} 1 & 0 & 0 \\ -4 & -5 & 30 \\ 2 & 4 & -4 \end{vmatrix}$ $(C_3 \to C_3 - 5C_1)$

$= (-1) \cdot (+1) \cdot \begin{vmatrix} -5 & 30 \\ 4 & -4 \end{vmatrix} = -(20 - 120) = +100$

$= 1 \cdot (-5) \cdot 6 + 0 \cdot 10 \cdot 2 + 5 \cdot (-4) \cdot 4 - [2 \cdot (-5) 5 + 4 \cdot 10 \cdot 1 + 6 \cdot (-4) \cdot 0]$

$= -30 - 80 - (-50 + 40)$

$= -110 - (-10) = -100$

240

Sarrus' rule