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Mathematics instruction and the tablet PC

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The use of tablet PCs in teaching is a relatively new phenomenon. A cross between a notebook computer and a personal digital assistant (PDA), the tablet PC has all of the features of a notebook with the additional capability that the screen can also be used for input. Tablet PCs are usually equipped with a stylus that allows the user to write on the screen. Handwriting recognition software converts this input into text for use with software such as internet browsers and email programs. As an educational tool, two of the most important features of the tablet PC are annotation and wireless communication. The annotation feature allows the user to write on almost any document much as one would annotate a printout of the same document. The wireless communication feature allows tablet PCs to share information with one another. The advantages of these features and their impact on the Murray State University (MSU) classroom will be discussed in the evaluation section.

Keywords: tablet PC; mathematical annotation; wireless communication

1. Introduction

Recent efforts to use technology to effectively facilitate learning and to rejuvenate the traditional lecture format, [1], have led to the widespread use of tablet PCs in mathematics and science teaching at Murray State University (MSU). The merits of the tablet PC in this context are discussed in [2]. The authors focus on the impact that lecture with the inclusion of inquiry-based learning via the Tablet PC can have on the students. They emphasize that student learning is enhanced with the improvement of technology for auditory and visual modes of learning. The use of tablet PCs at MSU has led to campus-wide discussion and coordination of effective university teaching, [3]. In this article, we discuss several uses of the tablet PC, their merits and their disadvantages. In particular, we discuss tablet efficacy in the single tablet and multiple tablet classroom. We present examples of their use in an interdisciplinary program. Finally, we discuss measurements of student reaction in the following summary table.

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Advantages	Disadvantages
Use of archived notes for student learning	Wireless connectivity challenges Additional technical support needed
Use of colour to emphasize work Ability to involve students in multi-tablet classroom and to encourage interaction between students	LaTeX DVI files cannot be imported into Windows Journal
Use of multiple programs to aid in student learning (Internet, Virtual TI and other software)	Math Journal recognition of mathematical symbols
Increase in student learning and ownership of that learning	

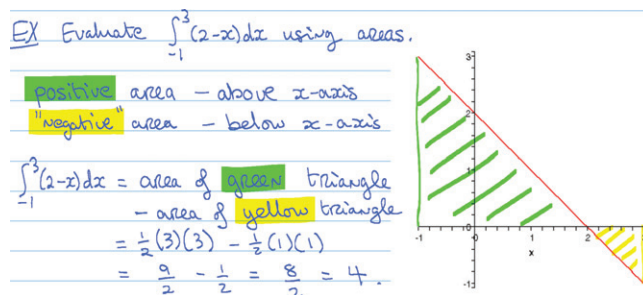


Figure 1. Use of colour to emphasize the mathematics of integration.

2. Single tablet classroom

The single tablet classroom has existed in various departments at MSU since 2004. The instructor uses a tablet PC as a lecture tool instead of more traditional blackboards, transparencies or Power Point. The tablet screen is displayed using an LCD projector so that students can see the instructor's desktop. The instructor can choose to generate freeform notes using Windows Journal, to annotate existing files such as Power Point presentations or Word files, to use mathematical software such as Virtual TI or Math Journal, to give the tablet to students or to archive their notes. See also [4].

Windows Journal is bundled with all tablet PCs. This software can be used to create notes on blank pages much like students would take notes on paper. The advantage of Windows Journal is that graphics from mathematical software like Maple or Virtual TI can be imported into the notes, see Figure 1. The multiple ink and highlighting colours allow the notes to be 'colour-rich' in much the same way that textbooks use colours. In particular, one can change colours when moving from theory to example and even from one example to the next. This use of colour is particularly useful for weak students who are not always aware of the transition from theory to example.

By annotating a base file the instructor can begin with a document that includes a class outline, perhaps with headings or even detailed theory. The instructor may then fill in the details as the class progresses. If necessary, additional pages can easily be created within

Example 4.3.6 If a single regular die is rolled, what is the probability of rolling an even number or a number greater than 3?

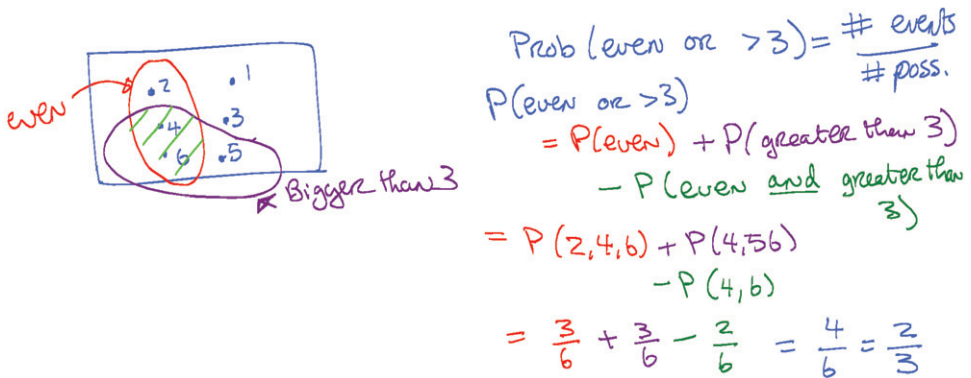


Figure 2. Use of prepared work and colour to increase understanding of probability concepts.

the document to provide space for answers to unanticipated questions. Some instructors use existing Power Point presentations or Microsoft Word documents as their base file, since these can be annotated from within Power Point or Word. Others use PDF files of LaTeX documents, which they annotate from within Windows Journal, see Figure 2. In our experience, Windows Journal could import all of the document types that we tested with the exception of LaTeX DVI files.

In addition, Math Journal [5] can use the power of the pen to carry out algebraic manipulations and solve mathematical equations. One challenge with Math Journal that our students experienced was that the software often failed to recognize the difference between the letter 's' and an integral sign. Math Journal's graphical displays were superior to those of Virtual TI and comparable to those of Maple. Math Journal can only be used with a tablet PC. We found the functionality of the graphics to explore calculus based concepts is better served with Virtual TI.

One of the ways that using a tablet PC can change the dynamics of a classroom or lecture hall is in the manner in which students present their work. Students are often unwilling to come to the front of a lecture room and present their work to their peers. Their discomfort is largely associated with the forum. In the presence of a wireless data projector, the tablet PC can subtly change that by allowing students to present their work from anywhere in the room. They do not even need to leave their seats! This ability allows the students to discuss mathematics with others around them, display their work, and then explain their results. It encourages team effort as well as individual creative thinking skills that are valuable for their future. The tablet PC is also very appealing to our current college students who are generally very comfortable with technology. Naturally, the 'cool factor' will fade over time. Although some may refer to this phenomenon as the Hawthorne effect [6], the students are learning the material and are able to explain it to others in a clear fashion. The thought that their performance is improved based on an increase in morale could be an argument, but the ability of the students to make their learning their own and to understand the mathematics so that their scores on homework and exams are subsequently better would tend to negate that argument. In Fall 2006, assessments were given to tablet based classrooms and to a control of a traditional classroom. The results of the tablet based classrooms showed a 10–15% improvement in their scores over the non-tablet based classroom.

By far the most significant impact on the learning environment has been the availability of archived notes. The instructor can easily save his/her class notes and make them available to students through course management software such as Blackboard or WebCT. Because of the availability of free viewer software for Word, Power Point and even Windows Journal files, the files can be posted in their original format. However, they can also be converted to PDF format using Adobe Acrobat Professional. This allows students without Microsoft Windows to access the files easily. By archiving lecture notes, instructors can provide an environment that facilitates different learning styles within the formal lecture environment. Some students learn well while taking notes. Others learn more effectively when they do not take notes, focusing all of their attention on the lecture. The availability of the instructor's original notes also allows students to assess the accuracy of their notes.

3. Multiple tablet classroom

The differences between a one tablet classroom and a multiple tablet setting create amazing opportunities as well as interesting challenges. In the multiple tablet setting, the understanding of the wireless communication software involved is vital. One must be patient to become proficient. The classroom in which this multiple tablet setting was used involved pre-teachers at the secondary school level. The interesting feature was that it was an introduction to proof course. In the past, the students dreaded this course and had extremely negative attitudes towards it. The inclusion of the tablet created several challenges with maintaining connectivity between the tablets. The class did involve lecturing at some point in the class, but the majority of the class involved the students developing, critiquing, and thinking about different strategies to attack problems. For example, students in groups were given different applied calculus problems. Then they would share the solutions wirelessly with all the students. This gave other students an opportunity to critique other's work and to learn how to work many more problems than one instructor could address in a class period.

The students had access to the tablets while in class only. The students used flash drives and saved what happened in class or downloaded the information from Blackboard after class. The structure of the class required the students to be prepared with a grasp on the definitions and the concepts prior to class. Then in class, problems would be addressed and work would be critiqued. A problem was given to the groups and copied into One Note, software that allows users to create a real-time whiteboard for brainstorming sessions. The students were all connected via their tablet computers to the One Note session. They would then try to solve the problem individually in Windows Journal. (It was determined that using Windows Journal gave more flexibility to colour and design for ease in copying into One Note.) If the individual was at an impasse, then a predetermined group partner for the day could help by beaming his/her problem work to the student. The group would then discuss further work. The students would then present their work in One Note.

Tablet etiquette is necessary to effectively move the class to a successful end. Each person (group) is given a number. When that number is called, that person submitted his/her work to One Note. If this procedure is not followed, then another's work could be copied over and sometimes lost. The advantage of using One Note is that it automatically saves work as one continues on the page. This allowed the students to see all solutions on their tablet PCs. The next phase related to the critique. Sometimes this occurred immediately. Other times the solutions were saved and critiques were assigned individually

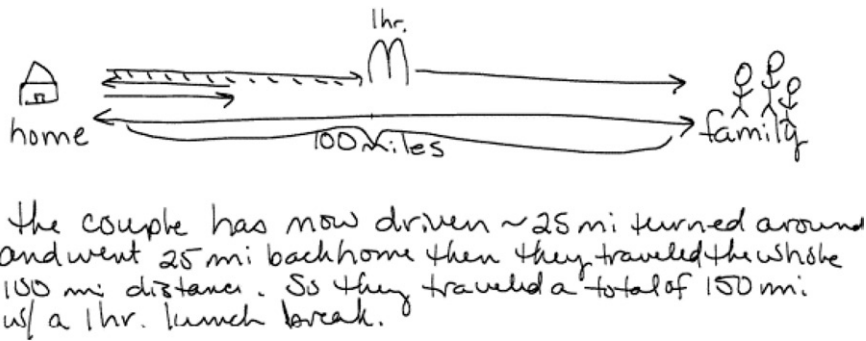


Figure 3. Student work related to distance and time problem discussed in Section 3. The student needs to better comprehend the meaning of different variables.

as homework. If it occurred in real time, then each person or team would think about the critique and then a given number was called and that group provided the written critique within the One Note document. Discussion would ensue (sometimes with considerable vigour) among the other class members.

An example from the first week of class is illustrated here. The problem was:

On Friday, a couple left in their car to travel 100 miles from their home. When they had driven about a quarter of the way, they realized they had forgotten an item. They drove home, retrieved the item, and immediately returned to their trip. This time they drove faster. Halfway to their destination, they stopped for an hour. Then they continued on their journey until they reached their destination. Graphically determine the distance travelled and the time elapsed.

The students need to graph distance in terms of time in a visual representation. Two examples of student understanding are given in Figures 3 and 4. In Figure 3, it is clear that the first student needs help with understanding the variables involved and the assumptions that need to be made. In Figure 4, the second student makes some assumptions, visually defines the problem, and uses colour to highlight the result.

The benefit of students using tablets to analyse and critique problems was two-fold. First, the students took ownership of their learning. They knew they would have to present their work and they wanted to be mathematically accurate. Second, they were excited to be in class! Upon comparison of exam scores given to this tablet class and to a non-tablet classroom, the scores for an identical exam involving proofs by contradiction, contrapositive, and induction were 16% higher for the tablet classroom. In addition, surveys given indicated that the students felt they had learned the concepts well.

4. Interdisciplinary learning

Within a recently funded National Science Foundation grant, Biology and Mathematics in Population Studies (BioMaPS), [7], the tablet has proved valuable to the biology and mathematics students and faculty involved. The BioMaPS program creates a research environment for mathematics and biology students to study the designs and patterns that exist in populations at the organismal and cellular levels. The project is motivated by the increased need for professionals who can understand the mathematics behind the biology and the biological implications of mathematical models. Within the research programs,

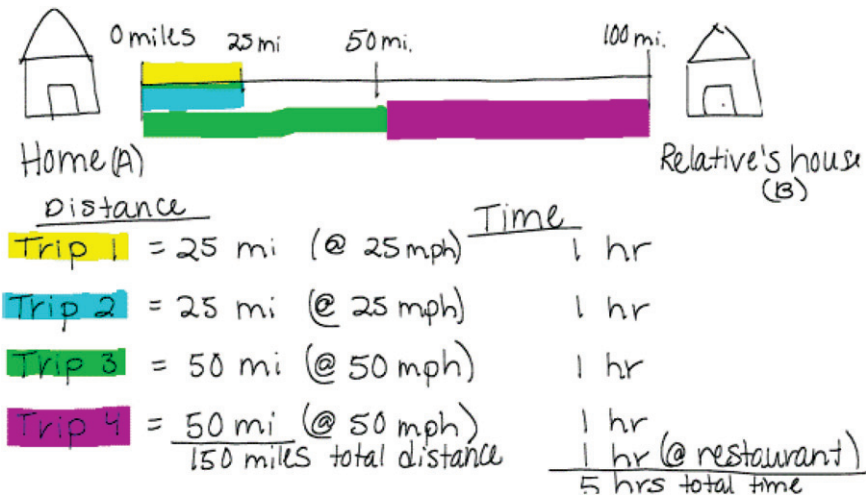


Figure 4. Student work related to distance and time problem from Section 3. The student makes some assumptions, visually defines the problem, and uses colour to highlight the result.

the objective is to equip students with the skills to understand such patterns and to develop accurate models of biomedical and ecological phenomena using methods from statistics, optimization and differential equations. The tablet enhances the research potential of all involved in the BioMaPS program.

During field experiments, students are able to document items on their tablet using different Microsoft products and then can immediately share that information with a student in another area in the field. The ability to collect data in multiple places and to share that data has been a tremendous benefit to the research conducted with the project. This strategy has the potential to decrease work load and to allow for further mathematical analysis of a larger data set. Also, tablet use has proven useful within a biology field experiment in which students have used a digital camera to document a particular species. They then share that graphic with colleagues via the tablet, who can then annotate the document to label anatomical structures and highlight environmental features. Since this is shared in real time, there are many opportunities to learn from others without consuming inordinate amounts of time searching for a given species.

5. Student evaluation

The single tablet classroom has been in use at MSU since 2004. About 682 students in 21 different courses, including 375 mathematics students in 14 sections of 10 different mathematics courses, were surveyed to assess their response to the use of the tablet as an instructional tool.

About 93.1% of students surveyed and 91.7% of mathematics students downloaded their professor's archived notes at some point during the semester. The vast majority (85.2%) did so at home. Of the 73.6% of mathematics students who still regularly took their own notes in class, 53.3% used their notes in conjunction with the archived notes to study for quiz or exams or to complete homework assignments. Of the 14.4% of mathematics students who did not take notes in class, 70% used the archived notes to study for quiz or exams or to complete homework assignments.

Of particular interest was student reaction to the single tablet classroom. Students were given a series of statements and asked to assess them based on the Likert Scale (1 strongly disagree, 2 disagree, 3 neutral, 4 agree, 5 strongly agree).

Mathematics students generally agreed with the statements:

'My professor's use of the Tablet PC during class increased his/her teaching effectiveness.'
(Mean 4.20 ± 0.19)

'My professor's use of the Tablet PC during class promoted student learning.'
(Mean 4.11 ± 0.17)

They generally disagreed with the statements:

'My professor's use of the Tablet PC during class did not create a better learning environment.'
(Mean 1.78 ± 0.19)

'My professor's use of the Tablet PC during class did not improve his/her interaction with students in the classroom.'
(Mean 1.95 ± 0.21)

With regard to archived notes, mathematics students considered their availability a good thing by rating the statement

'Having access to archived notes promoted student learning.'
(Mean 4.37 ± 0.17)

6. Concluding remarks

The tablet PC has enhanced the learning environment for many mathematics students at MSU. Whether in a single tablet classroom or a multiple tablet classroom, the evidence suggests that the students are benefiting from the archived notes and the instructor's commitment to engage students with different learning styles through the use of tablet PCs.

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