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Using a Tablet PC To Enhance Student Engagement and Learning in an Introductory Organic Chemistry Course

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Since 2004, a group of faculty members has been developing and investigating various instructional models involving the tablet PC. Both authors have been involved in these efforts in the areas of instructional design and assessment. This article describes the integration of a tablet PC into an introductory organic chemistry course and is written from the perspective of the chemistry instructor (JRC).

In 1979, the first of many articles in the "computer series" appeared in this *Journal* and described the use of computers in chemical education *(1)*. Needless to say, over the past 28 years, computer and software technologies have improved tremendously and have assumed ever-expanding roles in chemical education. Whether it is in the collection of data, computer-assisted instruction and simulations, or computational–visualization pedagogies, computers have become an integral part of the chemistry classroom and laboratory *(2–15)*. For the most part, Web-based applications and the development of new computer software have been the driving force for integrating computer technology in chemical education over the past 15 years *(16–21)*. One notable enhancement in the computer itself came in 2002 with the reintroduction and expansion of pen-based computers in the form of tablet PCs. Since that time many software programs, such as Microsoft (MS) Office, have become pen-enabled and instructors across disciplines have used tablet PC-based technology in diverse teaching, learning, and research environments *(22–31)*.

A tablet PC is a versatile computer system that can have the computing power of a laptop or desktop computer along with a digitized pen for enhanced functionality such as handwriting recognition, freehand drawing, and the ability to annotate documents with digital ink *(32)*. The pen can be used as a mouse to navigate through software menus by tapping the screen. Currently, the two major types of tablet PCs are slates, which lack an attached keyboard, and convertibles, which come with an attached keyboard. Both models have integrated wireless cards that allow the pen-based capabilities of the tablet PC to be combined with mobile computing opportunities. Pen-enabled software such as the MS Office Suite, MS Windows Journal, and MS One Note provide a robust electronic solution for taking or delivering notes in recreational, business, or academic environments.

This article describes the transformation of a second-semester course (CHE 106)[1] in the chemistry sequence typically referred to as general, organic, and biochemistry (GOB). Students in this class are typically in the allied health areas (nursing, nutrition, dietetics, occupational safety and health) or the agricultural sciences. In general, approximately three-fourths of the material in this course is in the area of introductory organic chemistry with the remaining material a survey of biochemical topics. The major change in the transformation of this course was the integration of a tablet PC to support the process and product of the lecture format. In other words, this technology supported instructional activities inside the classroom and provided students a rich set of notes (product of the lecture) to use outside of class.

Traditional Format

In the traditional lecture format for CHE 106, the instructor used a standard desktop computer running PowerPoint slides and a data projector to guide discussion, present long definitions, and display problems to be solved. A chalkboard near the screen was also used to write additional notes and to solve problems. The chalkboard was behind a long lecture bench and the instructor spent a great deal of time during class behind this bench with his back turned away from the students writing on the chalkboard.

The PowerPoint slides were made available to the students before class on Blackboard (course management system) so they could print and use them during class to add the material written on the chalkboard. Approximately once a week, the instructor placed students in groups (typically 3–4 students) and had them work a variety of problems related to course concepts. At the end of each group session, the instructor would solve the problems on the chalkboard or ask one or more students to come to the board and participate in solving the problems. Showing student work is a great way to get students actively involved in the class and display productive and non-productive strategies to problem solving. However, at times it was quite difficult to organize students participating at the chalkboard owing to space limitations at the front of the room and time constraints in a 50 minute lecture.

The instructor taught this course a total of three times (three different semesters) in this format with a total of 81 students. Four regular examinations were given during each semester with a series of online quizzes delivered through Blackboard. The online quizzes gave students an opportunity for frequent feedback on mastery of course concepts. The exams consisted of a combination of multiple-choice, short answer, and discussion questions. At the end of each semester, the organic chemistry sections (A and B) of the ACS GOB 2000 Standardized Exam[2] was given as the final exam. Only the organic sections of this exam were given because the biochemistry content in CHE 106 can be highly variable in different semesters.

One-Tablet Model of Instruction

After teaching CHE 106 for three semesters in the traditional format, the instructor integrated a single tablet PC into the lecture portion of the course. Many educators are studying multi-tablet strategies where the instructor and most or all of the students in class have tablet PCs *(22)*. However, for a variety of reasons, there is a need to investigate the educational value and opportunities associated with the pen-based technology of a single tablet PC. For example, the one-tablet model is much more cost effective compared to a model where the instructor and all students in the class have a computer (1:1 computing environment). Although some universities are mandating students purchase specific computer systems, such as tablet PCs, it is still uncommon to find a 1:1 computing arrangement at most colleges and universities.

Although this model only employs a single tablet PC, it is not a teacher-only tablet since students use the tablet PC in group exercises. In fact, previous reports have documented numerous ways to integrate a single tablet PC into chemistry, physics, and engineering courses *(24, 27, 32, 33)*. Since there are many ways to integrate a single tablet PC into the pedagogical framework of a course, it can be quite difficult to dissect which uses of the tablet PC have merit or educational value. Therefore, a study was designed in which specific elements of tablet-based instruction were implemented in a course along with an assessment protocol that involved measuring students' attitudes and direct learning gains. CHE 106 was an excellent choice for this study on the one-tablet model because the instructor taught this course on a regular basis and learning gains could be investigated using the ACS GOB 2000 Standardized Exam.

One-Tablet Format (Phase I)

The major difference between the tablet-enhanced and traditional format of CHE 106 was the introduction of pen-based technology associated with a tablet PC. The instructor taught CHE 106 a total of three times in phase I of the one-tablet format with a total of 122 students. The same number and types of exams and quizzes were given in both the one-tablet courses and traditional courses with the ACS GOB 2000 Standardized Exam serving as the final examination.

The integration of a tablet PC into CHE 106 provided a computer system that was lightweight and mobile, had integrated wireless capabilities, and a pen to place digital ink in pen-enabled software to generate electronic notes and documents. In the one-tablet format, PowerPoint slides were imported into Windows Journal and contained many blank spaces and pages for writing during class (guided notes). Based on previous experiences and other work *(34)*, the instructor is a strong advocate of using pre-made slides to guide discussion and present problems. This approach allows problems to be worked out in class by hand, with student input, to model problem-solving strategies. Using the guided-notes approach in the one-tablet format, the pre-made slides and anything written or drawn during class are integrated together in a single, electronic document.

Since the tablet PC serves as a digital whiteboard, anything the instructor used to write or draw on the chalkboard, in the traditional format, was written on the tablet PC and projected on a large screen in the classroom, which was a 150-seat auditorium. Students in the classroom, especially in the back of the room, are better able to see the projected tablet screen and what is being written in the notes, compared to using the chalkboard. The writing and annotation tools available on a tablet PC also allow an instructor to create a rich set of lecture notes with a variety of colors and highlighting *(24)*. For example, when discussing the nomenclature of organic compounds, the instructor always highlighted the longest continuous chain with a yellow highlighter and any substituents with a blue highlighter (Figure 1). When teaching nomenclature on the chalkboard, the structures would sometimes become messy and difficult to interpret because of all the chalk marks identifying important parts of the molecule.

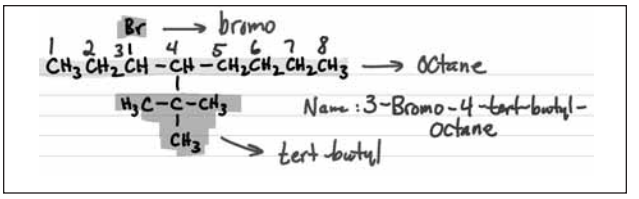

Figure 1. An example of electronic notes generated on a tablet PC in Windows Journal. The shading in the alkyl bromide above was either yellow (longest continuous chain) or blue (substituents) highlighting.

The tablet PC changed the dynamic between the instructor and students in the classroom. The tablet PC was positioned such that the instructor never had to turn his back to the students, which was often the case when using a chalkboard. The instructor was always facing the class when working problems or drawing diagrams on the tablet PC. In addition, the instructor was not trapped behind the large lecture bench and was able to move more freely around the class. This allowed him to get better student input before annotating the note pages. If the tablet PC was connected to the data projector using a cable, even though the instructor was better able to move around the classroom, he had to return to the tablet PC to annotate the notes. However, in our setup the data projector had wireless capabilities and the instructor was able to take advantage of the mobile technology of the tablet PC to show slides and write notes anywhere in the class without being tethered to the data projector cable. Since he could walk anywhere in class, especially in the back to get these students involved, the instructor usually had a few podiums placed in the classroom where he could stop to write notes (Figure 2).

Figure 2. A one-tablet class with the tablet PC connected to a wireless data projector. In this picture, the instructor is writing on the tablet PC positioned on a podium in the middle of the classroom.

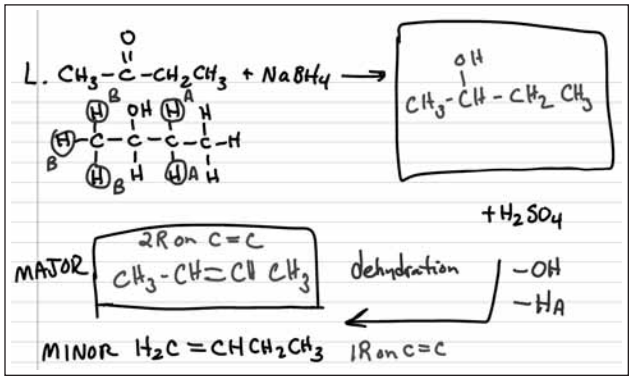

Figure 3. An example of electronic notes generated on a tablet PC in Windows Journal. These notes were constructed in class when the tablet PC was connected to a wireless data projector. The structures in the boxes were drawn by student volunteers during class.

Figure 4. Members of a student group answering a problem on the tablet PC.

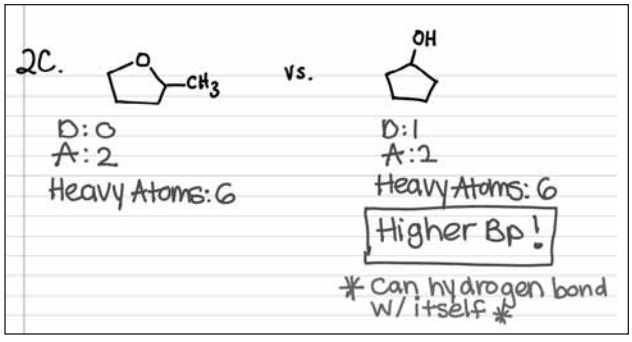

Figure 5. An example of electronic notes generated on a tablet PC in Windows Journal. A representative from a student group wrote the answer to this problem concerning the boiling points of two organic compounds. D refers to the number of H-bond donors and A refers to the number of H-bond acceptors.

An interesting feature of wireless projection is that the instructor would often hand the tablet PC to a student volunteer to work a problem or draw the structure of a product or reactant for a reaction we were discussing (Figure 3). From his or her seat, a student could easily and directly participate in class and even if the structure was not correct, it promoted excellent discussion on productive and non-productive problem-solving strategies. Students in this course knew that class time was for analyzing both good and bad chemistry and drawing an incorrect structure is part of the learning process. As in the traditional format, students were placed in groups to work problems in the one-tablet format. Each group was asked to provide answers to one or more questions on the tablet PC. Since there was just one tablet PC, it was passed around the room to the different groups. Typically, one member of the group served as scribe and wrote the group answers to the questions in Windows Journal (Figure 4). Since the class saw the instructor use the tablet PC, they were comfortable using the software or pen to write the answers.

An example of an answer to a question asked during the group exercises concerning the boiling points of organic compounds is shown in Figure 5. Since each group would start on a different problem in these sessions, all of the answers could be collected on the tablet PC during the time allotted for solving the problems. This left an appropriate quantity of time at the end of class for discussion. Occasionally, the instructor would ask a representative from a group to present and defend the answers to questions in front of the class. Typically, the tablet PC was not connected to the data projector while the student groups were placing their answers on the tablet PC. However, once discussion of the problems and answers began, the tablet PC screen was projected to show student work. Overall, the tablet PC provided an efficient and effective way to get students involved in classroom activities and to analyze many different types of problems.

All of the notes generated in class and group exercises were in an electronic format and archived for continuous student access. Typically, the notes were in Windows Journal format (.jnt) and students would download a freeware Journal viewer to view and print the notes. It should be noted that the inking and annotating described in this article can also be performed directly in PowerPoint or other pen-enabled software and thus the archived notes can be made available as .jnt, .ppt, .pdf, or .html files. For CHE 106, the notes were made available in Blackboard in .jnt format.

One of the most controversial aspects of the one-tablet model may be the archiving of lecture notes. It is likely that many chemistry students at all levels do not succeed because they lack a complete and accurate set of notes in which to study and learn the material outside of class. The archived lecture notes derived from the tablet PC may help these students and provide a quality product of the lecture that will complement the textbook and other learning resources. Possible negative outcomes of providing lecture notes are that students may not regularly attend class or sit passively in class. Although quantitative data on student attendance are not available, there was no discernible difference in student attendance in the traditional and tablet-enhanced formats.

Studies have demonstrated the educational value of students taking their own notes during class *(35)*. Therefore, even though a complete and accurate set of notes was available right after class, the instructor encouraged students in the one-tablet

courses to take notes during class. A total of 106 students in the one-tablet courses took an informational survey and the data indicate that 98 students (92.5%) utilized the archived lecture notes available on Blackboard. Of these 98 students, 89 (90.8%) of them reported that they took their own notes during class. A majority of these students also indicated that they used the archived notes along with their notes to study or added their in-class notes to the archived notes to make a master set of notes. A total of nine (8.5%) students in the three one-tablet courses reported that they did not take notes during class. However, on the comments section of the survey, six of these students indicated they are not good note takers and learn best if they listen in class and are not distracted by taking notes. Overall, it does not seem that the availability of archived lecture notes promoted student passivity in the one-tablet sections of CHE 106.

Besides providing a quality product of the lecture, the archived notes benefit students who have to miss class for legitimate reasons. In addition, each time CHE 106 is taught it is typical to have two or three students that require a note taker during class because of issues associated with a learning disability. In the one-tablet courses, these students relied on the archived lecture notes and not another student in the class to take good notes.

Assessment Data for the One-Tablet Format

As mentioned previously, 106 students out of 122 enrolled in the one-tablet courses completed a voluntary attitudinal and informational survey concerning the one-tablet model of instruction. The results of the attitudinal portion of the survey administered in the one-tablet CHE 106 courses were recently published with data from other chemistry, physics, and engineering courses *(33)*. These data also appear in Table 1 because it is complementary to the data on learning gains in the one-tablet format. Overall, it is clear that students in CHE 106 had a positive attitude toward tablet-based instruction and believe that a tablet PC is an effective tool in enhancing teaching and learning. One caveat with these data is that students who completed this survey have never taken CHE 106 in the traditional format. However, most of the students have usually taken several introductory science courses that did not use tablet technology prior to taking CHE 106. Therefore, these students are in an appropriate position to comment on the value of the tablet-enhanced format.

Although student attitudinal data are interesting and insightful, direct learning gains are also needed to establish the educational value of a particular teaching methodology. Since the ACS GOB 2000 Standardized Exam (organic chemistry A and B, 60 questions) was given in the traditional and one-tablet courses, the results of the test can be analyzed to investigate learning gains in CHE 106. Since the standardized test is a required final exam, all 122 students in the one-tablet courses completed the test. The raw scores obtained in each course format were placed in 10-point groups in order to visualize and analyze the complete distribution of scores (Figure 6).

Overall, there was a statistically significant difference in the mean test score of students taught with the traditional approach compared with those taught with the one-tablet approach: 30.59 ± 0.74 and 36.34 ± 0.74, respectively (Wilcoxon 2-sample test, $p < 0.001$). The number of students scoring within specific 10-point ranges on the test (10–19, 20–29, 30–39, 40–49, and 50–59 points) in each course format was determined to visualize and analyze the distribution of scores (Figure 6). For example, the number of students who correctly answered between 30 and 39 questions out of a total of 60 on the standardized test was placed in the 30 category. There was a statistically significant difference in the distribution of students among the five score categories in the traditional and tablet-enhanced data sets ($\chi^2 = 18.0, p < 0.001$). Further analysis showed that this overall difference was due to significant differences in the 40 and 20 categories ($\chi^2 = 12.4, p < 0.001$; $\chi^2 = 3.8, p = 0.05$; respectively).

The data in Figure 6 indicate that there is a shift to higher standardized test scores when the one-tablet model was adopted in CHE 106. The most striking and significant difference is found in the number of students scoring in the 40 group. The standardized test used in this study was designed to measure broad content knowledge in the area of introductory organic chemistry. Therefore, a reasonable conclusion from the data in

Table 1. Results from an Attitudinal Survey on the One-Tablet Model of Instruction

Question[a]	CHE 106[b]
My professor's use of the tablet PC during class increased his or her teaching effectiveness.	4.71 ± 0.06
My professor's use of the tablet PC during class did not create a better learning environment.	1.34 ± 0.07
My professor's use of the tablet PC during class promoted student learning.	4.64 ± 0.07
My professor's use of the tablet PC during class did not improve his or her interaction with students in the class.	1.44 ± 0.08
Having access to archived lecture notes promoted student learning.	4.68 ± 0.06

[a]Answers were based on the Likert Scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree) with certain questions negatively worded. [b]The data presented are average ± standard error and 106 students that participated in the survey.

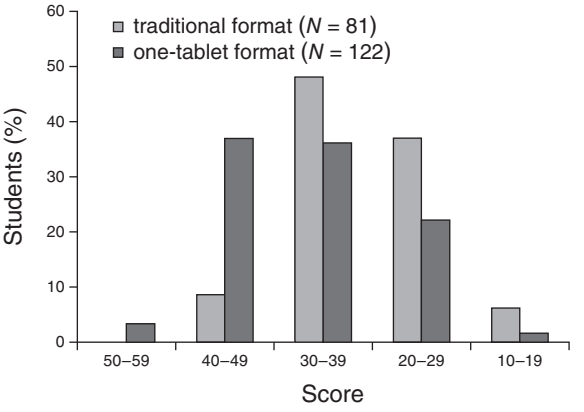

Figure 6. A graphical representation of the percentage of students that scored in a particular score range on the organic chemistry sections of the ACS GOB 2000 Standardized Exam.

Figure 6 is that students in the one-tablet courses have achieved a greater content knowledge of introductory organic chemistry and that learning gains have been achieved as a result of the pedagogical practices made available with the pen-based technology of the tablet PC.

One-Tablet Format (Phase II)

The data from the attitudinal survey (Table 1) and standardized test (Figure 6) demonstrate the educational value of phase I of the one-tablet model. However, there are many other ways to integrate a single tablet PC into CHE 106 that may further enhance student learning. Overall, there is excellent pedagogical synergism between the pen-based technology of the tablet PC and many other instructional approaches such as holding virtual office hours (Web conferencing), podcasting, conducting peer-led exercises with "clickers", and making instructional movies with screen capturing software *(27, 33, 36)*.

Additional phases of this study in CHE 106 will incorporate all of the practices in phase I along with some combination of these other tablet-based instructional methods. A phased approach to investigating educational value is absolutely necessary in identifying best practices associated with this technology to maximize student learning.

Conclusion

The process and product of the lecture in an introductory organic chemistry course has been transformed through the use of tablet PC technology. Data from a student attitudinal survey, along with results from a standardized test, indicate that this was a positive transformation in terms of student reaction and learning outcomes. This transformation was the first phase in a study to identify the roles that pen-based technology can play in chemical education.

As can be found in this *Journal*, chemical educators are always investigating new and innovative ways to improve chemical education. Some educators are turning away from the traditional lecture in favor of a more guided-inquiry approach *(37, 38)*. Others in chemistry and related disciplines have noted the problems with the traditional lecture format, but see value in redesigning this format to improve teaching and learning *(39–41)*. This article described how technology can be used to redesign a lecture format that can have positive outcomes in terms of teaching and learning. It was certainly more than just the simple presence of a tablet PC in the course that led to greater student achievement. The tablet PC fostered enhanced engagement of students with the instructor, other students, and the material. Indeed, the tablet PC was just a teaching tool used to promote instructional diversity and effective classroom practices that positively affected student learning.

"A Tool, Not a Gimmick" was the title of the first computer series article in this *Journal (1)*. Some 28 years after its publication, there remains little doubt about the validity of this title. In fact, as indicated in the conclusion of the original computer series article, computers are tools that will not replace teachers but rather enhance many aspects of the teaching–learning experience by promoting good teaching by skilled practitioners.

Acknowledgments

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Notes

1. CHE 106 is a four credit hour course with three 50-minute lectures and one two-hour lab per week. The tablet PC was not used in the laboratory portion of the course.

2 The standardized exam is published by the Examinations Institute of the Division of Chemical Education of the American Chemical Society.

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Supplement

Student exam scores from the organic section of the ACS GOB 2000 Standardized Exam