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## Background Research Paper No. 31

# Gauging Instructional Effectiveness of Open Policy for Wireless Computers in Classrooms

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Open-policy wireless laptop usage in classrooms in recent years has received some unfavorable media attention. Ideally, mobile computers would be used to take notes and search for relevant information. If misused, however, they may be a distraction to students and to instructors. Currently there is a wide and continuous spectrum between the two polarities of approaching computer usage in classrooms practiced by different instructors. Extremes are perhaps exemplified by two physics professors, one making full use of Tablet PCs and DyKnow Software (Fort Hays State University, 2010), and the other smashing a student laptop after cooling it in liquid nitrogen (SideWalkSurfer9, 2010).

So, do the benefits of in-class computer usage exceed the disadvantages? Or vice versa? In a feature titled "Students Stop Surfing After Being Shown How In-Class Laptop Use Lowers Test Scores" The *Chronicle of Higher Education* reports about a professor who identified 17 students in one of her classes who were using laptops most frequently and found that they did 11 percent worse, on average, than their peers on the first test (Fischman, 2009). In a more comprehensive study, Fried (2008) showed that students who use wireless laptops in classes are indeed frequently distracted from the task at hand, which negatively reflects on their performance. In a recent *Washington Post* article with another indicative title: “More colleges, professors shutting down laptops and other digital distractions”, Mortkowitz (2010), cites a variety of sources that question the educational benefits of allowing students to use computers in classrooms.

Barak, et al. (2006) investigated the feasibility of using laptops in large classrooms and found their directed use successfully supported students’ active learning and problem-solving activities. Laptops also facilitated meaningful student-to-student and student-to-instructor interactions. However, a fraction of students (12% in the study) used their laptops for non-directed (non-learning) purposes, such as Web surfing and e-mail messaging. Similarly 15% of students in the study indicated that the wireless laptops distracted their attention in class. Barak at al. conclude that wireless laptops should be employed in class only when the instructor requires the students to do so.

A recent study by Sisson (2009; Sisson, 2010) shows that when this is achieved, the positive results can be substantial. She allocated one of the three weekly class periods in introductory physics course to problem solving and deployed Tablet PCs combined with interactive software (DyKnow) to facilitate collaborative work during the sessions. She saw considerable test score increase as measured by final exam scores (11% improvement in calculus based course and 7% in algebra based course). Also, the student retention rate significantly increased in both courses compared to the historical 5-year average. The increase was greater than one-standard deviation (to 67% student success) in the first semester calculus based course and greater than two-standard deviations (to nearly 80%) in the first semester algebra-based physics (Sisson, 2009).

Mortkowitz (2010), however, with respect to Tablet computers contends: “Tablets such as the iPad will only make it harder for students to pay attention in class and for schools to ban devices. Because the iPad can be used to read textbooks, professors might be unsure which students are goofing off and which are studying. Seton Hill University in Pennsylvania doesn't seem to mind. In fall 2010, the school is going to give each incoming student a MacBook and an iPad. How distracted will those students be?”

This question concerned us as well when we attempted to use wireless computers to improve student learning, active engagement and overall experience in a lecture setting of an introductory algebra based course in physics at Columbus State University in Columbus, Georgia.

## Purpose and Research Questions

The goal of the authors was to maximize productive use of available personal mobile computers (laptops and tablet PCs) in order to improve student learning in a lecture setting. For this purpose, in Spring semester of 2010 we utilized DyKnow software in an algebra-based introductory physics course, in order to increase student active participation in lecture and to facilitate productive note taking. Our intention was to maximize student learning while minimizing or eliminating the harmful effect of distracting features associated with wireless computers in classrooms. The main advantages associated with using DyKnow software, include (Hrepic, et al., 2009):

1. The elimination of students' need to blindly copy the content because presented slides and annotations are automatically transferred to students' computers, permitting students instead to think about the content and personalize instructor's annotations

2. The availability of multiple channels of real-time feedback to instructor (such as status understanding, chat, pooling and slide submission)

3. group work is facilitated through simultaneous annotations of slides and content exchange between students and instructor and among students.

In essence, we were aiming to increase active engagement and student collaboration in this lecture course because positive effects of those approaches are broadly documented in science education literature.

Consequently, with DyKnow, we were hoping to improve the quality of the lecture (Hrepic, et al., 2009). DyKnow can be utilized with laptops as well as with tablet PCs but unlike laptops, Tablet PCs allow for handwritten electronic inking which is extremely handy in areas that use a lot of symbolic annotations such as physics, other sciences, math, engineering (as well as music, Japanese language visual arts etc.).

A note is necessary with respect to convenience of note-taking enabled by DyKnow software. All Science, Technology, Engineering, and Mathematics (STEM) majors are well aware of the hardship of effectively following very condensed, very high paced content with highly symbolic language. Frequently, they have a choice between either recording the notes as written on the chalkboard/whiteboard during the class time, or effectively following the conceptual meaning of the presentation. For this reason, any technology that enables eliminating the rote copying of material comes as a great advantage. However, writing (and rewriting) the content is one of the common ways of learning, and one perceived as critical in learning of highly symbolic fields. This does not present a problem when all students use tablet PCs because they can annotate the content using their electronic inking capability. However, laptops in this respect present a challenge because they do not provide for this convenience. Effective note-taking strategies when laptops are used with DyKnow would have to incorporate some paper and pencil annotations.

In addition to expecting primarily laptop computers with our students, another disadvantage in applying DyKnow software in our setting was that students are not required to have either laptops or tablet PCs so we could only rely on students' voluntary participation for bringing wireless ready computers to classes. This situation, that would be common to many other universities, resulted in a variety of unknown factors that we faced at the beginning of deployment and it was necessary to optimize the technology usage early in semester, when classes already started - based on the number (i.e. fraction) of students who had computers.

In this study, the instructor chose not to use the monitoring features of DyKnow software. DyKnow monitor is part of the software package that enables instructor to control various aspects of students' computers. For example, the instructor can disable running of certain programs (or all but certain programs) of students computers. Or s/he can enable the opening of only certain URLs from the browser. We did not use this feature because as long as the student does not log onto DyKnow s/he is in control of his computer. So it was possible that some students may opt not to even log on if they wanted to do any other, un-related activity on their computer.

The most important unknown factor to determine at the beginning of the study was the fraction of students who own wireless ready computers and who could, at least in principle, bring them to classes and use with DyKnow. It turned out that out of 51 students present on the first day of classes, 46 owned a wireless ready laptop. This was a promising start but in order to get students to bring computers to classes it was crucial to organize computer-facilitated activities that will make it worthwhile for them to bring computers. With consistent DyKnow usage, the number of students who had their laptop in class soon stabilized around 60% of the attendees (with attendance number typically in lower to mid 40-ies). The 60% usage rate was less than optimal, but it was sufficient to enable the majority of students to capitalize on interactive features of the software and was also sufficient for the instructor to gauge understanding of most of the present students by utilizing interactive feedback tools.

Formative assessment tools (such as pooling, status of understanding and slide submission) were used regularly during the semester. Students were very responsive when giving feedback through "status of understanding" feature (Fort Hays State University, 2010) or while answering multiple-choice questions. Virtually all students logged into DyKnow were consistently providing responses. Students were also very actively submitting slides in response to open-ended questions and problems. Because not all of the students used computers to provide feedback, it was also necessary to resort to traditional, verbal methods of eliciting questions to ensure that everybody is keeping up. The seating arrangement in the lecture room consisted of single row chair desks with tablet arms that were as wide as the seating. This limited area available to students could have been a disadvantage to laptop users because the space was not sufficient for comfortable placement of laptop and paper note pads.

In this setting, we were interested to answer the following research questions:

1. Given possible advantages and disadvantages of using this technology in a voluntary manner, will it be beneficial for students to bring computers to classes?

2. Will tablet PC users, if any, perform differently than students using laptops?

3. How will students perceive advantages and disadvantages of using this technology?

4. Will students consider the inability to take handwritten notes with laptops a disadvantage?

## Research Methods

In order to answer our research questions, we used several data collection modes. First, a classroom observation by an external evaluator during which the lecture was videotaped from the back of the classroom, with an eye to observing student note-taking behaviors, use of DyKnow software and student engagement in (or distraction from) the lesson. Second, the students were given extra credit for participating in a comprehensive, end-of-semester online survey that gauged both their usage patterns and attitudes regarding the use of wireless computers and DyKnow in aiding their learning. Third, the class participated as a whole in a focus group session run by the same external evaluator, allowing them to further express attitudes and opinions regarding the advantages and disadvantages of using this technology as learning support in this physics class. The survey was administered before the focus group to minimize the possible bias that could happen with opposite order. The collected data was then examined to determine possible correlations between usage patterns and standard measures of student performance (such as test scores and the final grade).

## Evaluation

### Observation Evaluation

An external evaluator attended this course in order to videotape a typical class session in which DyKnow software was being used to support student learning and problem solving in class. Of interest for the videotaped observation were the following questions:

- How are those mobile computing resources being used? Are these uses on-task, or are students using computers in ways that distract them from the learning experience

- Do mobile computers and DyKnow software facilitate productive note-taking for students?

- Does DyKnow software facilitate interactive learning environments in the classroom, via "status of understanding" or other interactions such as shared annotation during problem solving?

By positioning the observer in the back of the classroom, the evaluator was able to look directly at the screens of many of the computer users in this lecture setting and directly document usage patterns.

Data obtained from this observation indicate that, in providing students with a framework for productive use of computing, the instructor was enabling students to direct these resources in a productive manner. During the entire class session, only one student with a laptop in use was briefly observed using that laptop for any task that was not related to the class. Students were able to follow the lecture presentation better by viewing the *PowerPoint* slides presented (an advantage, given the projector and room setup made viewing the screen difficult for many students). Students were also observed using the laptops to facilitate group work and submit that work to the instructor in real time. One student was also observed following along in the electronic textbook simultaneously with the lecture, and annotating the presentation accordingly.

Not all of the students in this observation had access to a laptop or tablet, even within the confines of a group problem solving session. There were multiple student groups that were working on assigned group problems solely on paper and pencil, and were unable to use mobile computing in order to communicate their results, interact with one another, with the instructor, or to request assistance.

Further, one of the potential benefits of using DyKnow software on laptops or tablet PCs is to allow better student note-taking. However, the desks were not big enough to permit students to use both the laptop and to take notes in a more traditional, paper-based format. Should any student find value in taking notes by hand and not have access to a tablet computer, that student would be unable to do so.

**Focus Group Evaluation**

Students were also asked to participate in a focus group in class. Students were asked to discuss the advantages and disadvantages of using the DyKnow software (either with laptops or Tablet PCs) in class. Focus group data was gathered anonymously, and the interviewer did not know whether individuals were computer users or not, unless the students self-identified.

During the focus group, 34 students participated in a discussion of the advantages and disadvantages of using DyKnow software (either with laptops or PCs) in class (out of 53 enrolled at the beginning of the semester, one of whom had dropped at the time of survey). Focus group responses to this are summarized in Table 1.

**Table 1**

**Student-reported advantages and disadvantages to DyKnow usage**

| | |
|---|---|
| Advantages | More interaction for the whole class<br>Easy to go back and review material<br>Helps students organize notes<br>Can telecommute to class<br>Allow you to focus on content, not note-taking<br>Can check status button without embarrassment |
| Disadvantages | If you have no computer, you are at a disadvantage<br>Technical issues can eat up class time.<br>Temptation to check email during class<br>Couldn’t take notes by hand if using laptop in class. |

Because of the small desk sizes, a discussion on note-taking surfaced during the focus group. Students perceived that those with tablet PCs held a distinct advantage if they were able to successfully take notes while following DyKnow in class, and were best able to perform in group work problem solving as well. Students with laptops perceived themselves to be at a disadvantage, as they needed the desk space for their computer, and were unable to take notes by hand on that desk. Further, students using laptops rather than tablet PCs found that participating in physics problem solving could be quite challenging in a setting in which they could not write (by hand) a solution directly onto the computer screen. The combination of these factors was perceived as creating an environment that advantaged the tablet users and disadvantaged others.

Students were further asked about disadvantages of using wireless computer technology in class. Focus group responses indicate that students are aware of potential distractions that a wireless computer can provide, and list the temptation to check email during class as a strong disadvantage.

Students were also aware of their inability to use the "status of understanding" feature if they did not have a computer in class, and perceived themselves to be at a disadvantage in interacting with the instructor in order to convey that information to influence the pacing and presentation of course material. We discuss this issue later while presenting relevant results obtained through the survey.

**Survey Evaluation**

Out of 53 students enrolled in class 14 days into the semester, 37 took the survey (69.8%). Only one student dropped the course (after the second test) and two more stopped attending (one after the first test and the other one after the second test – the latter of those took the survey). Another 15 did not take the survey. All respondents indicated they personally owned a computer: a desktop (17) a laptop (with no pen input) (29), a Tablet PC (3), or more than one of these types (like a desktop and a laptop 11). Six students indicated they owned a desktop only.

Frequency distribution of bringing the wireless computer to classes is shown in Table 2 along with corresponding scores of students in each category. We examined whether bringing a computer to classes and participating in DyKnow sessions was related to learning (as measured by average scores of the taken tests and by their overall success in the course). In the table below, we group students according to their reported frequency of bringing computer to physics classes (For easier reference this is categorized by numbers from 5-always to 0-never). We display results related to each individual answer and then group these answers into fewer number of categories shown on the right side of the table and we compare the scores of those groups as well.

The patterns of computer usage and DyKnow activity, determined through survey were compared to three different measures of student performance collected during the semester. Those measures included:

1. The average scores of all taken tests. This measure is not affected by a missed or not taken test. All test questions were standard and slightly modified end-of-the chapter, open-ended problems typical for algebra-based introductory physics course.

2. The test score calculated by algorithm defined in syllabus. The course involved three during-the-semester tests and the final exam. The lowest of the semester test scores was dropped. The final exam score could not be dropped and it had the same weight as the other two tests. This measure is important because it better reflects the true success in the testing component of the course grade. At the same time this measure is obviously affected by any missed score (three students who took the survey did not take the final

exam and in this measure their final test score counts as zero).

3. The end of the semester score which combined the test results (72%), homework (22%) and quizzes (6%). This measure represents a true course success and it directly determined the final grade score before possible extra credit was added. This score was also affected by a homework which was completely taken online and quizzes which were partially taken in class and partially online.

Since our samples were not randomly assigned, we used nonparametric statistics (Kruskal-Wallis 1-way ANOVA for comparing 3 and more groups and Mann-Whitney U-test *p*-values for two group comparison).

**Table 2**

**Comparison of Frequency of Students' Computer Usage with Success Level**

| **In Spring 2010, on average** | | Cate-gory | All and Each Category | | | Categories 5 vs 4,3,2,1 vs 0 | | | Categories 5 vs 4,3,2,1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I was bringing my computer to physics class:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of Taken Tests | All responses: | | 37 | 60.88 | 22.92 | | | | | | |
| | Three times per week (all) | **5** | 21 | 67.49 | 18.20 | 21 | 67.49 | 18.20 | 21 | 67.49 | 18.20 |
| | Two times per week | **4** | 1 | 10.67 | NA | 8 | 45.03 | 25.80 | 8 | 45.03 | 25.80 |
| | Once per week | **3** | 3 | 49.44 | 15.67 | | | | | | |
| | Once or twice per month | **2** | 3 | 48.08 | 37.13 | | | | | | |
| | Once or twice in semester | **1** | 1 | 57.00 | NA | | | | | | |
| | Never | **0** | 8 | 59.39 | 25.85 | 8 | 59.39 | 25.85 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.365** | | | **p=0.121** | | | **p=0.040** | |
| **I was bringing my computer to physics class:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Test Score Per Sylla-bus Algo-rithm | All responses: | | 37 | 65.16 | 24.85 | | | | | | |
| | Three times per week (all) | **5** | 21 | 73.62 | 17.31 | 21 | 73.62 | 17.31 | 21 | 73.62 | 17.31 |
| | Two times per week | **4** | 1 | 9.67 | NA | 8 | 45.83 | 28.82 | 8 | 45.83 | 28.82 |
| | Once per week | **3** | 3 | 48.19 | 23.14 | | | | | | |
| | Once or twice per month | **2** | 3 | 51.81 | 39.92 | | | | | | |
| | Once or twice in semester | **1** | 1 | 57.00 | NA | | | | | | |
| | Never | **0** | 8 | 62.29 | 28.93 | 8 | 62.29 | 28.93 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.293** | | | **p=0.097** | | | **p=0.022** | |
| **I was bringing my computer to physics class:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All responses: | | 37 | 72.26 | 22.51 | | | | | | |
| | Three times per week (all) | **5** | 21 | 80.12 | 15.35 | 21 | 80.12 | 15.35 | 21 | 80.12 | 15.35 |
| | Two times per week | **4** | 1 | 30.17 | NA | 8 | 56.66 | 23.25 | 8 | 56.66 | 23.25 |
| | Once per week | **3** | 3 | 59.41 | 18.93 | | | | | | |
| | Once or twice per month | **2** | 3 | 60.19 | 33.51 | | | | | | |
| | Once or twice in semester | **1** | 1 | 64.34 | NA | | | | | | |
| | Never | **0** | 8 | 67.24 | 30.01 | 8 | 67.24 | 30.01 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.350** | | | **p=0.101** | | | **p=0.019** | |

The category split indicates that students who brought computers most frequently to classes performed better according to both the test scores and the course grade. However, students who never brought computers performed better than those who brought them in occasionally. This might be an indication that students who did not bring computers to class consistently either did not use them effectively or they used computers for activities not related to the course. We found no significant difference between averages of all individual groups. Comparison of the categories 5 (always) vs. 0 (never) vs. 4,3,2,1 (everything else) show difference significant to 0.1 level according to average test scores ($p$=0.097). Comparison between "always" users and other computer users (with non-users omitted) is significant at the 0.05 level according to all three dependent measures.

As Table 3 shows, the correlation between the laptop presence and our dependent variables is also significant: at 0.1 level with average Test scores ($p$=0.063), and at 0.05 level with respect to both syllabus-adjusted test scores ($p$=0.034) and the final grade ($p$=0.028). We used bivariate Spearman's Rho, as nonparametric correlation test.

**Table 3**

**Nonparametric correlations (Spearman's rho) between several independent variables (for computer users only) and dependent measures of student success**

| *Independent Variables* | *Spearman's rho Correlation* | *Avg. Scores Of Taken Tests* | *Test Score Per Syllabus Algorithm* | *Course Grade Result* |
|---|---|---|---|---|
| Frequency of Computer Usage | Coefficient ($\rho_S$) | .350 | .396* | .409* |
| | Sig. (2-tailed); N=29 | .063 | .034 | .028 |
| CSU GPA before Spring 2010 | Coefficient ($\rho_S$) | .471* | .484** | .502** |
| | Sig. (2-tailed); N=28 | .012 | .009 | .006 |
| SAT Math | Coefficient ($\rho_S$) | .672** | .667** | .686** |
| | Sig. (2-tailed); N=20 | .001 | .001 | .001 |
| CSU Math Placement Test | Coefficient ($\rho_S$) | .502* | .494* | .492* |
| | Sig. (2-tailed); N=21 | .021 | .023 | .024 |
| HS GPA | Coefficient ($\rho_S$) | .304 | .237 | .287 |
| | Sig. (2-tailed); N=24 | .149 | .265 | .174 |

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

In Table 3 we also compare these correlations with several kinds of background scores that usually highly correlate with student success in college courses in general (College and HS GPA) and physics courses in particular (Math scores). We find that SAT Math scores correlate higher with the three dependent measures than any other independent variable in Table 3. At the same time correlation of computer presence (for computer users) with success measures is significant at the same level ($p<0.05$) as correlation of success measures with the CSU Math Placement Scores (used to determine freshman initial math knowledge and appropriate level of math they need to take). Further, the computer presence (for those who used them) has been a better predictor for student success than their HS GPA in this course.

If survey participants who did not use computers are also included in this analysis (with usage frequency score 0), the correlation of computer presence and success variables drops because non-users performed better than occasional users but the overall correlation is still positive with coefficients $\rho_S$=0.199 ($p$=0.238) for average scores of taken tests and $\rho_S$=0.194 ($p$=0.249) for course grades.

In order to gauge possible adverse effects of off-task computer use during the class time, in further analysis we group students according to their self-reported active participation. Table 4 below shows how frequently survey participants logged on to DyKnow during the class time and whether they actively participated in lecture and activities when logged on.

**Table 4**

**Student DyKnow Activity in Lecture**

| | Always | Most of the time | Sometimes | Rarely | Never |
|---|---|---|---|---|---|
| **When / I did bring the laptop to the class, I logged on to DyKnow session:** | 26 | 2 | 1 | 0 | **0** |
| **When I logged on to DyKnow session, I used DyKnow to follow and participate in / lecture and activities** | **22** | **7** | **0** | **0** | **0** |

Answers to questions shown in Table 4 individually combined with the frequency of bringing laptop to classes (Table 2), served to create another set of user categories which more comprehensively addresses the computer and DyKnow activity level of each student. These categories are shown in Table 5. Students who never brought computers are classified into their own category (if students indicated they never bring computer to classes, the other two questions were skipped for them). Students who did bring computers were classified according to lowest frequency they selected in any of the three questions above. In this way, category "Always" represents students who always bring computers, always log on to DyKnow and always actively participate. The category "rarely" may represent a student who rarely brings computer but when s/he does s/he always logs on and always participates.

To match the scale of answer choices shown in Table 4, we converted answer choices shown in Table 2 according to the following scheme and than selected the lowest score between same types of choices: Three times per week = Always (5); Two times per week = Most of the time (4); Once per week = Sometimes (3); Once or twice per month or Once or twice in semester = Rarely (2); Never = Never (1). Thus, groups shown in Table 5 categorize students according to actual (i.e. claimed) participation level, as opposed to only frequency of bringing computer to classes. Table 5 below shows described categories and corresponding averages of our dependent measures.

**Table 5**

**Comparison of Students' Computer & DyKnow Activity with Success Level**

| **Minimum answer among following three statements** | | Cate-gory | All and Each Category | | | Categories 5 vs 4,3,2,1 vs 0 | | | Categories 5 vs 4,3,2,1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **I bring computer AND I log on to DyKnow AND I actively participate:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of Taken Tests | All responses | | 37 | 60.88 | 22.92 | | | | | | |
| | Always | **5** | 14 | 65.29 | 15.22 | 14 | 65.29 | 15.22 | 14 | 65.29 | 15.22 |
| | Most of the time | **4** | 7 | 63.20 | 33.24 | 15 | 57.57 | 27.73 | 15 | 57.57 | 27.73 |
| | Sometimes | **3** | 4 | 54.96 | 16.89 | | | | | | |
| | Rarely | **2** | 4 | 50.31 | 30.64 | | | | | | |
| | Never | **1** | 0 | NA | NA | | | | | | |
| | I never bring computer | **0** | 8 | 59.39 | 25.85 | 8 | 59.39 | 25.85 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.735** | | | **p=0.857** | | | **p=0.541** | |
| **I bring computer AND I log on to DyKnow AND I actively participate:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Test Score Per Sylla-bus Algo-rithm | All responses | | 37 | 65.16 | 24.85 | | | | | | |
| | Always | **5** | 14 | 72.27 | 14.54 | 14 | 72.27 | 14.54 | 14 | 72.27 | 14.54 |
| | Most of the time | **4** | 7 | 66.65 | 34.04 | 15 | 60.06 | 29.82 | 15 | 60.06 | 29.82 |
| | Sometimes | **3** | 4 | 55.47 | 23.86 | | | | | | |
| | Rarely | **2** | 4 | 53.11 | 32.70 | | | | | | |
| | Never | **1** | 0 | NA | NA | | | | | | |
| | I never bring computer | **0** | 8 | 62.29 | 28.93 | 8 | 62.29 | 28.93 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.703** | | | **p=0.804** | | | **p=0.395** | |
| **I bring computer AND I log on to DyKnow AND I actively participate:** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All responses | | 37 | 72.26 | 22.51 | | | | | | |
| | Always | **5** | 14 | 79.53 | 12.32 | 14 | 79.53 | 12.32 | 14 | 79.53 | 12.32 |
| | Most of the time | **4** | 7 | 73.99 | 28.77 | 15 | 68.17 | 25.04 | 15 | 68.17 | 25.04 |
| | Sometimes | **3** | 4 | 64.91 | 18.98 | | | | | | |
| | Rarely | **2** | 4 | 61.23 | 27.44 | | | | | | |
| | Never | **1** | 0 | NA | NA | | | | | | |
| | I never bring computer | **0** | 8 | 67.24 | 30.01 | 8 | 67.24 | 30.01 | | | |
| | (1,2) Kruskal-Wallis and (3) Mann-Whitney U-test p-values | | | **p=0.674** | | | **p=0.817** | | | **p=0.407** | |

Unlike comparisons between the laptop usage categories and dependent measures of student success, the differences between results of these categories are not significant. However, a closer look into averages of these categories show some distinct traits. The comparison of all categories show the level of success in all three dependent measures very regularly drops from the most frequent/active users down to less frequent users. And then, the scores jump up for students who never bring computers. This is graphically shown in Figure 1.

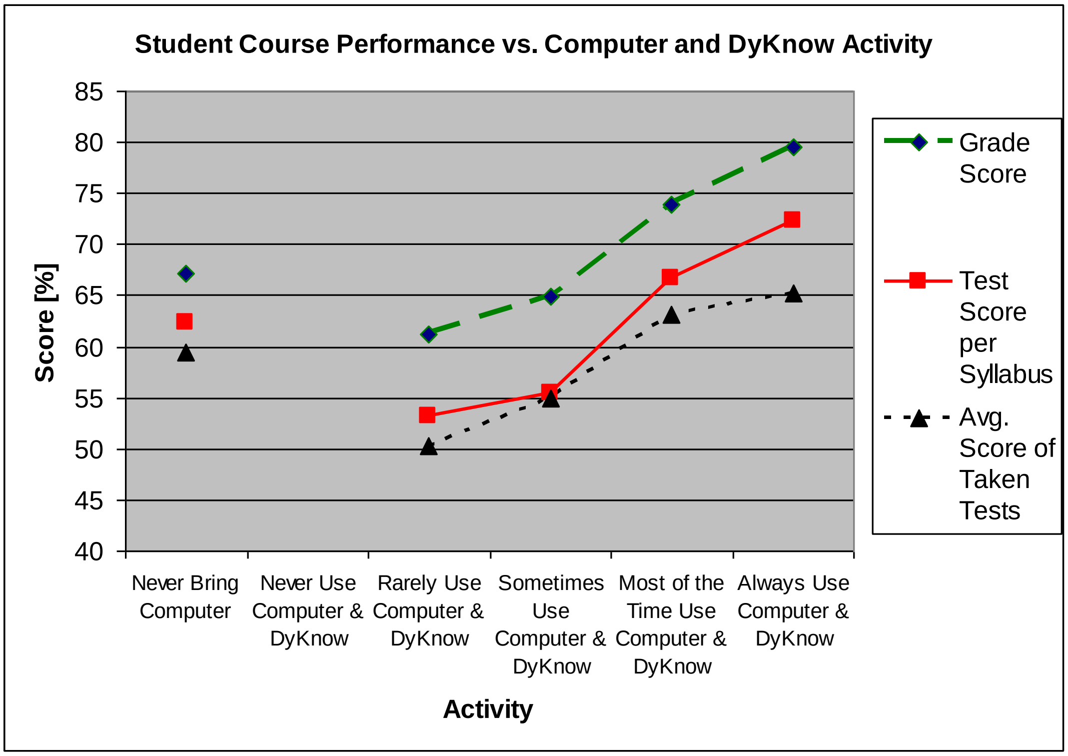


**Figure 1. Student scores measured against Cumulative Computer Presence DyKnow Activity**

Table 5 also shows that if "always" students (per cumulative computing activity) are compared to those who never bring computers and to those in other intermediate activity categories, the "always" users performed about a grade better than other computer users and also about a grade better than non-computer users. However the differences between mean scores in these categories are not significant. Namely, it so happens that if "always" users are omitted, average scores of other users fall just around the same level as those of non-computer users. So the relationship between the dependent measures among the computer users in this case is more informative than the comparison between all subcategories.

Table 6 compares scores and main categories described in Table 2 and Table 3 with two background measures for students (SAT Math, and HS GPA). Both of these background data was available for 23 students (out of 37 who took the survey).

**Table 6**

**Comparison of Students' Computer & DyKnow Activity with Success Level**

| | | | | *Tests Taken* | *Tests Syla* | *Grade* | *SAT Math* | *HS GPA* |
|---|---|---|---|---|---|---|---|---|
| I bring my computer to physics class: (Table 2 Subcategories) | **3 x week** | **N=12** | **Avg** | **69.6** | **74.9** | **81.3** | **552.5** | **3.27** |
| | | | SD | 18.1 | 18.1 | 16.0 | 60.3 | 0.33 |
| | **Inconsistent** | **N=6** | **Avg** | **43.4** | **43.1** | **54.8** | **475.0** | **3.35** |
| | | | SD | 30.3 | 33.57 | 27.2 | 88.3 | 0.55 |
| | **Never** | **N=5** | **Avg** | **58.4** | **61.0** | **67.7** | **500.0** | **3.22** |
| | | | SD | 29.2 | 33.7 | 32.7 | 111.8 | 0.21 |
| I bring computer AND I log on to DyKnow AND I actively participate (Table 3 Subcategories) | **Always** | **N=7** | **Avg** | **67.0** | **73.4** | **81.4** | **520.0** | **3.05** |
| | | | SD | 15.0 | 15.4 | 12.0 | 21.9 | 0.26 |
| | **Inconsistent** | **N=11** | **Avg** | **57** | **58.5** | **66.8** | **530.9** | **3.38** |
| | | | SD | 30.3 | 33.0 | 27.5 | 97.9 | 0.43 |
| | **Never** | **N=5** | **Avg** | **58.4** | **61.0** | **67.7** | **500.0** | **3.22** |
| | | | SD | 29.2 | 33.7 | 32.7 | 99.7 | 0.38 |

When these background measures are compared with respect to simple presence of computer in classes, we find that among the three main student categories (using computer 3 times a week, never, and in-between/inconsistent) the highest SAT Math score has the 3xWeek group, which also scores highest in out three independent measures. However, HS GPA is highest for the "Inconsistent" group which has the lowest dependent measures scores. Further, when "always" student users per cumulative computing activity are compared to inconsistent users and non-users we find that the inconsistent user group scores highest in both SAT Math and HS GPA. Yet, consistent users performed the best in all three dependent measures.

## Profiling Those Who Did Not Take the Survey

We asked ourselves if it might be possible that students who took the survey scored better and used technology more frequently than those that did not take the survey. To answer this question, we look into grades and average test scores of students who did not participate in the survey.

The incentive for students to take the survey was extra credit worth 0.4% of total grade and students who did not take this extra credit opportunity belong to two opposite ends of performers. Some of them scored high enough so they did not need this extra credit, while others did not take it because they did not think the extra credit will sufficiently help their grade. For this reason, as it turns out, the scores obtained from the survey participants are not skewed with respect to the overall class population.

It was possible to classify non-participants into categories according to how frequently they brought computer to classroom into simple "Yes" and "No" groups because the instructor knew all students by name and they sat at the same seats throughout the semester. Students whom the instructor could not classify with certainty into one of those two categories (primarily because they occasionally had computers rather than either always or never) were left as a separate “Not known" category. Within this population, one student dropped the course and another four students did not take the final. It is understandable that larger proportion of students who gave up in one of these two ways before the end of the semester would not take the survey. Most of these five students (3) are classified in the “Yes computer” category, but this category again has higher average than the “No computer” category. This is because the other three students in this category scored very high. Their reason for not taking the survey is also obvious - they did not care for this extra credit enough to take the survey.

Grades and test scores of students who did not participate in the survey indicate that the scores obtained from the survey participants are not skewed with respect to the overall class population.

**Table 7**

**Performance of students who did not take the survey**

| According to instructor’s observation, I was bringing my computer to physics class: | | Code | N | Avg. | SD | Dropped (included in analyzed 16) | Did not take final (included in analyzed 16) |
|---|---|---|---|---|---|---|---|
| Avg. Scores Of Taken Tests | All | | 16 | 43.17 | 26.44 | 1 | 4 |
| | Yes - always, mostly | Yes | 6 | 52.07 | 29.57 | 1 | 2 |
| | No - rarely, never | No | 6 | 30.26 | 19.78 | | 1 |
| | Status not known with confidence | | 4 | 49.16 | 29.11 | | 1 |
| | Mann-Whitney U-test between Yes & No | | | p=0.200 | | | |
| Test Score Per Syllabus Algorithm | All | | 16 | 44.28 | 31.37 | 1 | 4 |
| | Yes - always, mostly | Yes | 6 | 52.54 | 38.72 | 1 | 2 |
| | No - rarely, never | No | 6 | 32.39 | 20.90 | | 1 |
| | Status not known with confidence | | 4 | 49.74 | 35.12 | | 1 |
| | Mann-Whitney U-test between Yes & No | | | p=0.423 | | | |
| Course Grade Result | All | | 16 | 46.36 | 30.32 | 1 | 4 |
| | Yes - always, mostly | Yes | 6 | 55.35 | 34.49 | 1 | 2 |
| | No - rarely, never | No | 6 | 34.42 | 21.85 | | 1 |
| | Status not known with confidence | | 4 | 50.78 | 36.65 | | 1 |
| | Mann-Whitney U-test between Yes & No | | | p=0.337 | | | |

This analysis has been included simply to show that greater response rate would not have changed or skewed the conclusions obtained through the surveyed student group. If anything, it seems that whole class participation would have reinforced rather than skewed or changed the conclusions based on the survey results.

## DyKnow Experience and Recommendations

For all 37 survey participants, this was the first time they had chance to use DyKnow and many of them (32) used the opportunity. A large majority of DyKnow users report using it at home/dorm (24) in addition to the classroom (28). Nine students used it elsewhere on campus (in computer labs or library) and another seven elsewhere outside campus. Five never used it. Outside the classroom, students reported using DyKnow on average 1.9 hours +/- 1.7 hours per week.

Overall, a large majority of students report positive attitudes about DyKnow. Table 8 below shows that this attitude depends on the type of computer that students used.

**Table 8**

**Students' Attitudes about DyKnow**

| Category | Statement: Using DyKnow … | Answer | All N= 37 | Tablet Users N=3 | Laptop Users N=27 | Desktop Users N=2 | Did Not Use DyKnow N=5 |
|---|---|---|---|---|---|---|---|
| General Positive | was enjoyable | Agree & SA* (%) | 81 | 100 | 81 | 50 | 80 |
| | | Disagree & SD** (%) | 19 | 0 | 19 | 50 | 20 |
| | made learning more fun | Agree & SA* (%) | 76 | 100 | 78 | 0 | 80 |
| | | Disagree & SD** (%) | 24 | 0 | 22 | 100 | 20 |
| General Negative | was very challenging | Agree & SA* (%) | 24 | 0 | 26 | 50 | 20 |
| | | Disagree & SD** (%) | 76 | 100 | 74 | 50 | 80 |
| | was very frustrating | Agree & SA* (%) | 24 | 0 | 26 | 50 | 20 |
| | | Disagree & SD** (%) | 76 | 100 | 74 | 50 | 80 |
| | was a waste of time | Agree & SA* (%) | 27 | 0 | 30 | 50 | 20 |
| | | Disagree & SD** (%) | 73 | 100 | 70 | 50 | 80 |
| Cognition | helped me take better notes | Agree & SA* (%) | 51 | 100 | 48 | 0 | 60 |
| | | Disagree & SD** (%) | 29 | 0 | 52 | 100 | 40 |
| | facilitated my learning | Agree & SA* (%) | 66 | 100 | 63 | 50 | 60 |
| | | Disagree & SD** (%) | 35 | 0 | 37 | 50 | 40 |
| | enhanced my understanding of the course material | Agree & SA* (%) | 68 | 100 | 70 | 0 | 60 |
| | | Disagree & SD** (%) | 32 | 0 | 30 | 100 | 40 |
| Commu-nication | enhanced my interaction with classmates | Agree & SA* (%) | 68 | 67 | 70 | 50 | 60 |
| | | Disagree & SD** (%) | 32 | 33 | 30 | 50 | 40 |
| | enhanced my interaction with the instructor | Agree & SA* (%) | 70 | 100 | 70 | 50 | 60 |
| | | Disagree & SD** (%) | 30 | 0 | 30 | 50 | 40 |
| Motiva-tion | made me more attentive | Agree & SA* (%) | 59 | 33 | 67 | 50 | 40 |
| | | Disagree & SD** (%) | 41 | 67 | 33 | 50 | 60 |
| | made me more motivated | Agree & SA* (%) | 59 | 100 | 59 | 50 | 40 |
| | | Disagree & SD** (%) | 41 | 0 | 41 | 50 | 60 |

*Agree and Strongly Agree; ** Disagree and Strongly Disagree

Table 8 displays users grouped according to the "top" mobile computer they used with DyKnow. In this hierarchy a laptop holds a lower place than a tablet PC but higher than desktop computers. Several students who did not ever bring computer to classes used DyKnow and this was possible by downloading and viewing files posted online. While laptop users outnumber all others by far with small numbers of students in other categories, it is visible that Tablet PC users had much more positive experience with the software than laptop users, and laptop users were more satisfied than desktop users. It is interesting that students who did not use DyKnow files on their personal computers (but simply through attending classes in which it was used to enhance interaction) also report quite positive attitudes toward it.

Table 9 shows average Likert scale scores associated with overall DyKnow experience and student recommendations for continued DyKnow usage in this particular course. We break results according to “top” mobile computer owned by respondents. We do not find statistically significant differences between the categories but we do see much larger averages for both - experience and recommendations  - by tablet PC users than by the other two groups.

**Table 9**

**DyKnow Experience And Students’ Recommendations For Future Usage In This Course**

| | | | DyKnow Experience | | | DyKnow recommendations | | |
|---|---|---|---|---|---|---|---|---|
| | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| I own: | All | | 37 | 3.51 | 1.17 | 37 | 3.57 | 1.26 |
| | Tablet | 3 | 3 | 4.33 | 0.58 | 3 | 4.67 | 0.58 |
| | Laptop | 2 | 28 | 3.43 | 1.23 | 28 | 3.46 | 1.32 |
| | Desktop | 1 | 6 | 3.50 | 1.05 | 6 | 3.50 | 1.05 |
| | None | 0 | 0 | NA | NA | 0 | NA | NA |
| | Kruskal-Wallis ANOVA | | | p=0.456 | | | p=0.295 | |

Of advantages that students listed for bringing the computer to classes, by far the most commonly cited were various aspects related to the ease of taking/obtaining notes (10), saving/accessing notes (7) and personalizing slides (5). The next grouping of responses was the ease of following the content (9). Very high response rates are also seen regarding the ease of seeing the screen on computer (8) (again, the projector and screen were difficult for many students to view in this particular classroom). Other advantages included being able to actively participate (4) and to use DyKnow (4).  A unique benefit, which may be of particular interest for distance learning, is the ability for students to actively, and interactively, participate in a synchronous classroom experience via DyKnow software (with Skype if two way voice communication is desired).

The most common reasons cited as disadvantages of bringing computers to class include the inconveniences of physically carrying laptop (8) closely followed by Internet distractions (7). The next most frequent reason was the inability to hand rite notes on laptop (4). Closely related to that one is, as students put it, a false feeling that it is not necessary to take notes (2). Other problems listed are issues with battery life (4) and technical problems with laptops or Internet (3). The issue with the space that the laptop takes on the desk was brought up by one (1) student in the survey. Some students specifically stated there are no disadvantages (4).

From these answers and from analysis of relationship between computer use in classroom and student success in the course, we can say that while on average directed computer usage is likely to help students to perform better, for some students computers can be  a distraction which might hurt their score. The answer below exemplifies one such student: “I don't think there are any advantages [of bringing computer to classes] because when I stopped taking my laptop to class I could focus better. DyKnow is great as a teaching aid though”

There is also a very important point related to learning through kinesthetic action of note taking. This is not an issue with tablet PCs but it is with laptops. Some students are aware of this issue, such as one quoted below in his response to question why s/he never used DyKnow in association with this class.

> I, as well as other students I spoke with, prefer the "old fashioned" method of learning - that is using pencil and paper. If I had used DyKnow, I probably wouldn't have taken as many in-class notes. These notes contributed to my success in this course. If I don't physically write new information down as I first hear it, I'm less likely to remember it.

Altogether five students stated they never used DyKnow. The remaining four (besides the one quoted above) stated this was because they did not have either laptop or Tablet PC but we pulled out the above quote because it exemplifies what we see as the second major reason that can cause adverse effect of computer usage (i.e. specifically laptop usage) in learning highly symbolic content such as physics.

Following this lead, we examined whether a student's performance correlated with the type of computer they owned. The results are shown in Table 10 for surveyed students. We found substantial differences between the computer types with tablet PC owners outperforming laptop owners by two letter grades and (exclusive) desktop owners by three letter grades. When tablet PC owners are compared to all other surveyed students, the difference becomes significant at 0.1 level by all dependent measures.

**Table 10**

**Comparison of the top mobile computer owned and Students' success: surveyed students included**

| | | Cate-gory | All and Each Category | | | Categories 3 vs 2,1,0 | | |
|---|---|---|---|---|---|---|---|---|
| **The top mobile computer I own** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of TakenTests | All responses: | | 37 | 60.88 | 22.92 | | | |
| | Tablet | **3** | 3 | 81.03 | 3.88 | 3 | 81.03 | 3.88 |
| | Laptop | **2** | 28 | 60.25 | 21.32 | | | |
| | Desktop | **1** | 6 | 53.75 | 31.84 | | | |
| | None | **0** | 0 | NA | NA | 34 | 59.10 | 23.06 |
| | Kruskal-Wallis (3 groups) i.e. | | | **p=0.162** | | | **p=0.059** | |
| **The top mobile computer I own** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Test Score Per Sylla-bus Algo-rithm | All responses: | | 37 | 65.16 | 24.85 | | | |
| | Tablet | **3** | 3 | 86.37 | 4.28 | 3 | 86.37 | 4.28 |
| | Laptop | **2** | 28 | 65.17 | 22.59 | | | |
| | Desktop | **1** | 6 | 54.54 | 35.74 | | | |
| | None | **0** | 0 | NA | NA | 34 | 63.29 | 25.06 |
| | Kruskal-Wallis (3 groups) i.e. Mann-Whitney (2 groups) | | | **p=0.181** | | | **p=0.066** | |
| **The top mobile computer I own** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All responses: | | 37 | 72.26 | 22.51 | | | |
| | Tablet | **3** | 3 | 90.72 | 2.69 | 3 | 90.72 | 2.69 |
| | Laptop | **2** | 28 | 72.80 | 19.58 | | | |
| | Desktop | **1** | 6 | 60.54 | 34.72 | | | |
| | None | **0** | 0 | NA | NA | 34 | 70.63 | 22.78 |
| | Kruskal-Wallis (3 groups) i.e. Mann-Whitney (2 groups) | | | **p=0.244** | | | **p=0.095** | |

In addition to three tablet PC owners who took the survey, one more student in class owned a Tablet PC (and was using it consistently). When those four are compared to the rest of the class the difference becomes even greater and significant at 0.05 level as shown in Table 11.

**Table 11**

**Comparison of the Tablet PC owners other students: All students included**

| | | Cate-gory | All and Each Category | | |
|---|---|---|---|---|---|
| **The top mobile computer I own** | | **Code** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of TakenTests | All | **2** | 53 | 55.53 | 25.15 |
| | Tablet | **1** | 4 | 81.96 | 3.67 |
| | Other | **0** | 49 | 53.38 | 24.93 |
| | Mann-Whitney (2 groups) | | | **p=0.016** | |
| **The top mobile computer I own** | | **Code** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All | **2** | 53 | 64.44 | 27.57 |
| | Tablet | **1** | 4 | 90.29 | 2.36 |
| | Other | **0** | 49 | 62.33 | 27.62 |
| | Mann-Whitney (2 groups) | | | **p=0.040** | |

Finally, in order to gauge possible advantages of tablet PCs compared to laptop computers, we compared only those students who stated that they always brought computers to classes, always logged on to DyKnow and always actively participated. Among those, there are two tablet PC users and 12 laptop users. This comparison reveals a significant difference in favor of tablet PC users (at 0.05 level) as shown in Table 12.

**Table 12**

**Comparison of Tablet PC and laptop users with maximum level of computer and DyKnow usage**

| | | Cate-gory | All and Each Category | | |
|---|---|---|---|---|---|
| **I always (1) bring computer AND (2) log on to DyKnow AND (3) actively participate. I own:** | | **Code** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of TakenTests | All | **2** | 14 | 65.29 | 15.22 |
| | Tablet | **1** | 2 | 79.50 | 4.01 |
| | Laptop (Only Other Type) | **0** | 12 | 62.92 | 15.15 |
| | Mann-Whitney (2 groups) | | | **p=0.044** | |
| **I always (1) bring computer AND (2) log on to DyKnow AND (3) actively participate. I own:** | | **Code** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All | **2** | 14 | 79.53 | 12.32 |
| | Tablet | **1** | 2 | 89.51 | 2.37 |
| | Laptop (Only Other Type) | **0** | 12 | 77.86 | 12.56 |
| | Mann-Whitney (2 groups) | | | **p=0.144** | |

A possible explanation for such strong outperformance of tablet PC users was the advantage of taking consistent handwritten notes and this would be possible not only on tablet PCs but also on paper. So in Table 13 we compare three tablet users with those who never brought computers to classes (among survey participants). The difference is here again very large but not significant. The difference however suggests there could be a layer of advantage in using Tablet PCs above the simple paper and pencil note taking with Tablet PC users scoring (81.0 +/- 3.9)% and non-users scoring (59.4 +/- 25.85)% on taken tests.

**Table 13**

**Comparison of tablet PC users with students who did not bring computers to classes**

| **In Spring 2010, I was bringing to classes** | | Cate-gory | All and Each Category | | |
|---|---|---|---|---|---|
| | | **Code** | **N** | **Avg. %** | **SD** |
| Avg. Scores Of TakenTests | All responses | **2** | 11 | 65.29 | 23.94 |
| | Tablet PCs | **1** | 3 | 81.03 | 3.88 |
| | No Computer | **0** | 8 | 59.39 | 25.85 |
| | Mann-Whitney (2 groups) | | | **p=0.307** | |
| **In Spring 2010, I was bringing to classes** | | **Code** | **N** | **Avg. %** | **SD** |
| Course Grade Result | All responses | **2** | 11 | 73.64 | 27.42 |
| | Tablet PCs | **1** | 3 | 90.72 | 2.69 |
| | No Computer | **0** | 8 | 67.24 | 30.01 |
| | Mann-Whitney (2 groups) | | | **p=0.414** | |

### DyKnow and Tablet PC: Overall Experience and Recommendations

Table 14 breaks DyKnow experience and recommendations per tablet PC using opportunity, either as a personally owned device or as a borrowed computer. The results show that students who owned tablet PCs were most pleased with them but those who had chance to use borrowed tablet PCs had better experience and higher recommendations than those who did not use tablet PCs.

**Table 14**

**DyKnow experience and recommendations per tablet PC using opportunity**

| | | Cate-gory | All and Each Category | | | Categories 2,1 vs 0 | | |
|---|---|---|---|---|---|---|---|---|
| **Did you have opportunity to use Tablet PC, either yours or borrowed, in Physics I this semester?** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| **DyKnow** Experience | All responses: | | 37 | 3.51 | 1.17 | | | |
| | Yes, I used my personal Tablet PC | **2** | 3 | 4.33 | 0.58 | 6 | 4.00 | 0.63 |
| | Yes, I used a borrowed Tablet PC | **1** | 3 | 3.67 | 0.58 | | | |
| | No, I did not use a Tablet PC | **0** | 31 | 3.42 | 1.23 | 31 | 3.42 | 1.23 |
| | Kruskal-Wallis i.e. Mann-Whitney | | | p=0.404 | | | p=0.312 | |
| **Did you have opportunity to use Tablet PC, either yours or borrowed, in Physics I this semester?** | | **Code** | **N** | **Avg. %** | **SD** | **N** | **Avg. %** | **SD** |
| **DyKnow Recommendations** | All responses: | | 37 | 3.57 | 1.26 | | | |
| | Yes, I used my personal Tablet PC | **2** | 3 | 4.67 | 0.58 | 6 | 4.33 | 0.52 |
| | Yes, I used a borrowed Tablet PC | **1** | 3 | 4.00 | 0.00 | | | |
| | No, I did not use a Tablet PC | **0** | 31 | 3.42 | 1.31 | 31 | 3.42 | 1.31 |
| | Kruskal-Wallis i.e. Mann-Whitney | | | p=0.176 | | | p=0.103 | |
| **Did you have opportunity to use Tablet PC, either yours or borrowed, in Physics I this semester?** | | **Code** | **N** | **Avg.** | **SD** | **N** | **Avg.** | **SD** |
| **Tablet PC Recommendations** | All responses: | | 37 | 3.51 | 1.17 | | | |
| | Yes, I used my personal Tablet PC | **2** | 3 | 4.67 | 0.58 | 6 | 4.50 | 0.55 |
| | Yes, I used a borrowed Tablet PC | **1** | 3 | 4.33 | 0.58 | | | |
| | No, I did not use a Tablet PC | **0** | 31 | 3.32 | 1.17 | 31 | 3.32 | 1.17 |
| | Kruskal-Wallis i.e. Mann-Whitney | | | p=0.057 | | | p=0.018 | |

Table 14 also shows that students who used tablet PCs highly recommend them. Students who did not have a chance to use tablet PCs were not asked the question about their experience. Students who saw others (the instructor and other students) using tablet PCs do not think as highly of them as the users themselves.

At the end of this section few notes are in place related to possible (in)ability of students to participate in DyKnow facilitated classroom interactions due to not owning a mobile computer (either a laptop or a tablet PC) and which surfaced during the focus group. Namely, this relationship is not straightforward because three laptop owners chose to never bring them to classes. And one of the six exclusive desktop owners was bringing a (borrowed) laptop to classes twice a week. So out of eight survey participants who never used computer in classes, five owned a desktop only. Also there were five students who reported at the beginning of the semester they do not have a wireless ready laptop they could bring to classes. Therefore it appears all of these five students participated in the survey. Among the five, three students stated DyKnow (as used in class) facilitated their learning although they did not use it themselves at all (2) or used it only at home (1). Thus, in this class there were two students (out of 53) who could not bring laptop because they did not own one and who also did not think DyKnow facilitated their learning.

## Conclusion

In this study we invited and encouraged students to voluntarily bring wireless-ready computers to introductory physics classes. We wanted to capitalize on wireless computer presence in classes by using DyKnow software to enhance student note-taking, group problem-solving and classroom interaction in all directions. We did not have control over either the type of computer that they bring or over the frequency with which they utilized the computers. We also did not exercise control over they way students utilized computers in class. We gauged students' computer usage through classroom observations, focus group and comprehensive end of the semester survey.

The comparison of usage patterns with several standard measures of student classroom performance revealed that consistent technology users largely outperformed students who inconsistently or occasionally used the technology. In addition, students who did not bring computers to classes also performed better than inconsistent users. Therefore while computers may be helpful tools in enhancing student learning but only if used in a directed way and consistently. Sporadic and/or inappropriate usage seems to hurt student performance.

In order to achieve productive directed usage, it is important that the instructor provides the means of active computer facilitated learning experience. If students are simply left to bring computers to classes and decide what to use them for, the temptation to do activities not related to class may be too strong and it is not likely that wireless computers will help in this scenario. This finding is consistent with the finding by Barak at al (2006).

We also found that tablet PC users performed much better than laptop or desktop owners. This seems to suggest that the concern mentioned at the beginning of the paper related to tablet computers may not be justified. However, closer look is necessary into this issue. The tablet PC users in the study were self-selected, and obviously highly motivated students who decided to spend large amounts of money to purchase these devices. Although we used non parametric statistics (because of nonrandom assignment to groups, because of this type of self-selection and because of low numbers of tablet PC users compared to other devices) the results should still be taken with some caution. Having that said, it is very indicative that tablet PC users clearly outperform other students who equally frequently and equally actively utilize computers and DyKnow software and they also outperform students who do not use computers and who take notes in a similar way in which tablet PC users do. Finally, tablet PC users show much larger satisfaction with DyKnow software and (based on the difference in their and other students recommendations for the software and the pen-based computing devices), Tablet PC users are much more likely to use this technology productively and consistently.

The possibilities of misusing these devices in classrooms if they are not used to actively facilitate learning are real and numerous. For this reason iPads, with their current functionalities do not appear to have the same advantages as tablet PCs do. The first reason is that iPads do not have stylus and while it could be possible to do pen-based input with them using external apps, incorporating a native, fully functional stylus into iPads does not seem to be the plan for near future. Equally importantly, iPads are primarily meant to be consumer devices and are not meant to serve to create the content. This results in tremendous amount of entertaining features and apps that they incorporate, which, given the issue with distractions associated with wireless devices, may have really work against their productive using classrooms even if effective than input becomes possible.

- Students are already well aware of the potential pitfalls of using computers in the classroom. If these issues can be addressed, there may be a good deal of student buy-in for this usage.

- In a classroom where computer usage is optional, students may not see the situation as if the computer users are gaining an open invitation benefit. Rather, they will likely perceive that in this situation students without computers may be placed at a disadvantage. If there is no campus policy about universal laptop ownership, students recommend that this technology be utilized primarily in a computerized classroom, in order to level the playing field.

- Not taking notes is not a good idea – can happen in physics/ science/math as students can not type the content and space for note pad might not be available.

    - Some students need to take notes by hand. If universal tablet adaptation is not possible, then some other means (such as extended table size) must be provided to students to facilitate their chosen learning styles.

- When some students use DyKnow software in classroom and some do not, it is necessary to supplement real-time feedback features such as status or pooling with some other strategy to involve students who do not have computers. Having non-users to think for themselves about the answer choices is not enough.

- If possible, it is much preferable to use rooms with tables rather than table chairs so students who use laptops have sufficient room for the computer and the paper notepad

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