Impact of a Classroom Interaction System on Student Learning[$]

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Abstract. We have developed and deployed a Web-based wireless classroom interaction system in a large-enrollment introductory physics lecture class that uses HP handheld computers (PDAs) to facilitate real-time two-way student interaction with the instructor. Our system is ahead of other "clicker" based systems that are primarily limited to multiple-choice responses. Our system allows for a variety of questions including short answer questions. It also allows for adaptive questioning and two-way communication that provides real-time feedback to the instructor. We have demonstrated learning gains in our courses through use of this technology compared to earlier technology (PRS) used in the same class. We have also shown that students who use PDAs more often in class are more likely to perform better in the course.

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INTRODUCTION

Educational research (e.g. [1]) has converged on the conclusion that students learn best when they actively construct their own knowledge. However, the structure of most large-enrollment lecture classes discourages active engagement. When an instructor in a college lecture class asks questions, typically only a few students respond.

Recently, many faculty members teaching large-enrollment physics classes have begun using "clickers" to pose multiple-choice questions and increase student interaction. But these systems, though robust limit the nature of interaction and feedback to the instructor. Also, they do not replicate the kinds of open-ended questions that students have to answer on other course assessments.

We believe that wireless mobile technology such as HP IPAQ Pocket PCs (also called handhelds or PDAs) offers a better solution. Through appropriately designed Web-based software we have greatly expanded the question types and improved the richness of interaction. This solution allows us to create a real-time adaptive classroom interaction system rather than merely a classroom response system.

In this study we compare students learning in two classes – one that used one-way, multiple-choice-based PRS (Personal Response System) that uses infrared "clickers" with those using HP handheld PDAs (Personal Digital Assistants).

RESEARCH QUESTIONS

The following research questions were framed to examine the impact of HP PDAs used in conjunction with reformed pedagogy on student learning:

Research Question 1: Did student learning as measured by similar course assessments (exams, homework, etc.) improve with PDAs relative to when PRS was used?

Research Question 2: Did students who used the PDAs as intended in class more frequently perform better than those who used the technology less frequently and vice versa?

LITERATURE REVIEW

An excellent review of classroom response systems and underlying pedagogy is provided by Judson & Sawada [2] and we found this review extremely helpful in redesigning the pedagogy for the course. Judson & Sawada point out that it was not merely the technology, but rather the use of appropriate pedagogy that resulted in improved learning. Indeed, they warned that "an electronic response system does not

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come pre-packaged in an interactive learning environment."

The overarching pedagogical principles that guided our approaches are elucidated by Hake [3] who demonstrated that students in interactive learning environments performed better on conceptual learning assessments than those in traditional instructional environments. In particular, we adapted Mazur's strategy of "Peer Instruction" [4] in our classroom. Students were asked a question over the system and asked to first respond individually. Next they were asked to discuss their responses with their neighbor and finally they were asked to respond again. Crouch and Mazur [5] found that this technique greatly improves student performance on the assessment and fosters interactive and collaborative learning.

TECHNOLOGY & PEDAGOGY

Since 1995 the Kansas State University Physics Department has implemented classroom response systems in its introductory physics classes. A review of the evolution of these systems has been presented earlier. [6] Since 2001 we have been using the infrared "clicker" system called PRS (Personal Response System). The PRS system allowed for multiple-choice questions. In 2004 we obtained 40 HP IPAQ Pocket PCs (PDAs) and have since developed and deployed a Web-based classroom interaction system. The "K-State InClass" software allows for several different question types. These include: multiple-choice questions, short-answer questions and ranking task questions. It also allows for sequenced adaptive questions where the system automatically asks students a follow-up question based on their responses to a question. Additionally, the students can also send a question or comment to the instructor during class that the instructor can receive on her/his computer. This option was rarely used unless requested by the instructor.

Both the PRS and PDA systems were implemented in a class taken by about 90 students. Almost all of these students are elementary education majors. Over 95% of them are women. The instructor teaching this class is very familiar with research-based pedagogy and uses Mazur's Peer Instruction during lecture. Typically about four or five questions were asked during each class period. The instructor responded to feedback provided based on students' responses.

METHODOLOGY

To compare the PRS and PDA systems, we used data collected from the students when the PRS system was used in Fall 2003 (N=64) and later when the PDA system was used in Fall 2005 (N=87). The instructor in both years was the same and there was no statistically significant difference in the student population in these two years based on GPAs, majors in college or gender breakdown. The course content and overall pedagogical strategy did not vary significantly between these two years. Importantly, the course assessments – test and exam questions did not vary significantly. Also, the final course grades were assigned based on a fixed scale which was identical between the two years.

Thus for the purposes of our study the main differences between the two semesters was that in one year the PRS system was used and in the other year the PDA system was used in class. The only other significant difference was the number of students enrolled in the class in these two semesters.

Our sources of data for this study included the following:

- Student course grades when the PRS system was used in Fall 2003 (N = 64)
- Student course grades when the PDA system was used in Fall 2005 (N= 87)
- Student data logs as they responded to questions posed by the instructor using the PDA system in Fall 2005 (N=87).

RESULTS & DISCUSSION

Course Performance: PRS vs. PDA

We compared student performance in the two semesters based on their overall course grade distribution. The results are shown in Figure 1.

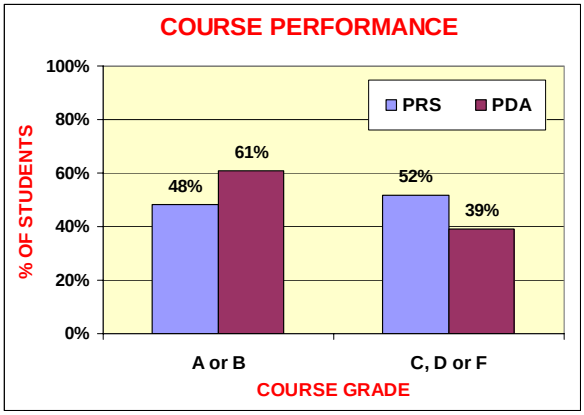

FIGURE 1: Course grades for PRS and PDA semesters

We find that there is a statistically significant difference in the grade distribution between the two semesters, with a significantly higher percentage of the PDA students scoring an 'A' or 'B' in the course compared with the PRS students. When the average

course GPA for the PRS students was compared with the PDA students, we find that there is a statistically significantly higher course GPA for PDAs (2.61) vs. PRS (2.31). A t-test showed a statistical significance at the $p<0.036$ level for a one-tailed test.

Relationship Between Course Performance and PDA Use

The previous result indicates that the overall course performance of the PDA group was superior to the PRS group. However, we were also interested in investigating whether the higher scoring students in the PDA group were in fact using the PDA technology more often. In other words, was there a correlation between use of PDAs in the classroom and student scores?

We recorded PDA usage by each student in the class based on how many questions the students responded to over the course of the semester. Students were not provided any incentive to respond to questions, thus their participation using the technology was purely voluntary. This was also the case for the PRS system.

A Pearson correlation analysis was conducted between the PDA usage and the overall score on course exams and tests combined. The results showed a weak correlation between PDA usage $R=0.37$, which was significant at the $F=0.0003$ level for $N=86$.

Further, we decided to compare the PDA usage for students in different grade bands. The results are shown in Figure 2 below.

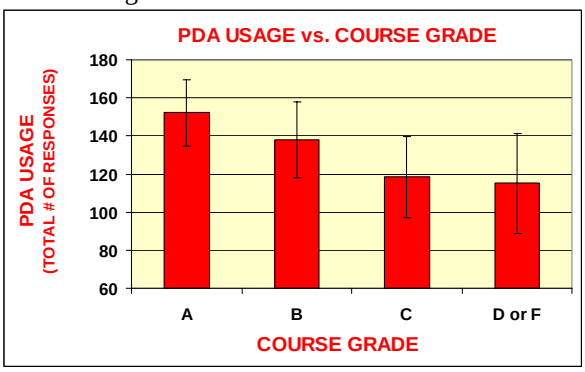

FIGURE 2: PDA usage for different course grades

We conducted an ANOVA for the PDA usage in different grade bands and found that there was a statistically significant difference in PDA usage between the grade bands shown in Figure 2 with a P-value = 0.030 (with F = 3.12 and $F_{Critical}$ = 2.71). Thus students who score a higher grade are significantly more likely to be using PDAs. However, is the converse also true?

We compared the course GPA for the students who were LOW, MEDIUM and HIGH users of PDAs in the classroom, where LOW is defined as students who responded to fewer than one-third of the questions posed, MEDIUM defined as students who responded to between one-third and two-third of the questions posed and HIGH defined as those who responded to more than two-thirds of the questions posed by the instructor on the PDA. The results are shown in Figure 3 below.

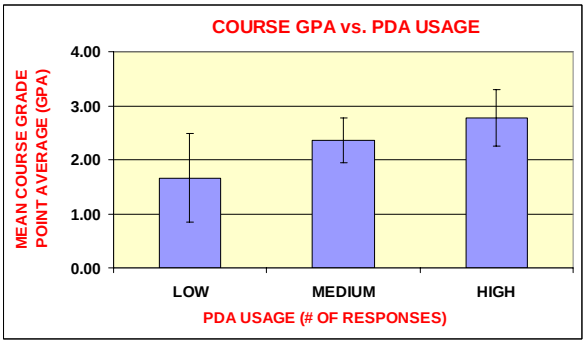

FIGURE 2: PDA usage for different course grades

We conducted an ANOVA for the PDA usage in three groups (LOW, MEDIUM, HIGH) and found that there was a statistically significant difference in average GPA of the three groups in Figure 3 with a P-value = 0.027 (with F = 3.76 and $F_{Critical}$ = 3.11). Thus students who use the PDAs more often are more likely to perform better on the course.

Summary

Overall, our data analysis above shows evidence of the following.

There is a statistically significant improvement in overall course grades after the PDA-based system was implemented. Before the PDA-based classroom interaction system was implemented (i.e. with the PRS system) about one-half of the students secured an A or a B in class. The following year, when the system was implemented nearly two-thirds of the students secured an A or a B in the class. Both of these courses in successive years were taught by the same instructor, covering the same content and using very similar and partly identical course assessments. The student population in these two courses was also statistically similar in terms of their SAT scores, etc.

In the class in which the PDA-based system was implemented, students who used the system more frequently in class performed statistically significantly better in terms of their mean score on the course assessments. Conversely, there was also a statistically significant difference between students getting an A, B, C or D/F in terms of their usage of the PDA-based system in class. Students who secured an A used the system much more often than students who got a D or F. This indicates that students who used the system in

class more frequently are likely to get higher grades and also that those who secure higher grades used the system in class more frequently.

Consistent with the result described above, a weak but statistically significant correlation was observed between PDA usage in the classroom and students' mean performance score on course assessments. Correlation does not imply causality, so these results do not imply that students' grades will improve merely by making them use the PDA-based classroom response system.

LIMITATIONS OF STUDY

As mentioned above, the main limitation of this study is that it does not demonstrate a direct causal relationship between use of PDAs in the classroom and superior performance. The students who used PDAs more often performed better on the course assessments. However, this does not mean that PDAs were responsible for their superior performance. One might argue that these were in fact "better" students who did several other things in the class that led them to perform better in the course assessments for reasons unrelated to the PDAs.

The only way to establish causality in this kind of study is to examine student behaviors of using the PDAs more carefully and investigate whether these were indeed responsible for superior performance. Such a study would be a natural extension of the present work.

CONCLUSIONS

We sought to address the following research questions in this study:

Research Question 1: Did student learning, as measured by similar course assessments (exams, homework, etc.) improve relative to before the project was implemented?

Yes, we did find a statistically significant improvement in course performance between the semester in which we had not used the PDA-based system and the one in which we did use the system for similar students and identical content and instruction.

Research Question 2: Did students who used the technology as intended in class more frequently perform better than those who used the technology less frequently and vice versa?

Yes, we did find that more frequent users secured higher course grades and conversely that students who secured higher course grades had used the system more frequently in the class.

In spite of the promising results above, as explained in the previous section, the results of this study must be viewed with caution because correlation does not imply causality.

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