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Improving Learning via Tablet-PC-based In-Class Assessment

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ABSTRACT

This paper describes research being carried out to support in-class assessment in large classes. The goal of the Classroom Learning Partner (CLP) is to increase instructor-student interaction and student learning by aggregating student digital ink answers and presenting results and representative answers to an instructor. The studies reported in this paper are the first phase of the research: They evaluates the use of Tablet PCs and a Tablet-PC-based classroom presentation system in an introductory computer science class. The presentation system, Classroom Presenter [1], supports student wireless submission of digital ink answers to in-class exercises. In this study, we evaluate the hypothesis that the use of such a system increases student learning by: (1) increasing student focus and attentiveness in class, (2) providing immediate feedback to both students and instructor about student misunderstandings, (3) enabling the instructor to adjust course material in real-time based upon student answers to in-class exercises, (4) increasing student satisfaction. The studies evaluate each of the above four parameters by means of classroom observation, surveys, and interviews; the second study compares results with a control class in which Tablet PCs were not used.

INTRODUCTION

Personal interaction between instructor and student in large classes is almost impossible. How can classes become more a two-way conversation between instructor and students? One way is to give students the ability to engage in hands-on activities that yield immediate feedback through interaction with instructors and peers. This technique has proven successful in large and small classes [2]. In large classrooms that employ a wireless polling system called Personal Response System, or PRS, for example, students use a transmitter to submit answers to multiple-choice, true and false, or matching questions. The results are tabulated and displayed in the form of a histogram on the instructor's computer. A system such as PRS provides a way for students to communicate their misunderstandings to an instructor. Instructors, however, are limited to asking questions having pre-existing sets of possible answers, i.e., close-ended questions, which assess recognition rather than recall.

In small classes, instructors can engage the students in a wider variety of in-class exercises than in large classes, since an instructor only has to evaluate a small number of answers. Students can work problems at a blackboard, on paper, or using pen-based computer systems [3, 4]. Can this technique be used in a large classroom, e.g., with 100 or more students, where the logistics of managing very large numbers of student answers could easily overwhelm an instructor?

The research described in this paper is the first phase in the development of a system, called the Classroom Learning Partner (CLP), that the first author's research group is developing to support in-class assessment in large classes. The Classroom Learning Partner (CLP) will support in-class exercises in a large class, while also enabling instructors to use the wide variety of exercises possible in small classes. The key idea: Aggregate student answers into a small number of equivalence classes by comparing those answers to instructor-specified correct answers and incorrect answers, and/or by clustering student answers. Then present the summary information to the instructor, e.g., in the form of a histogram and example answers.

CLP is being built on top of an existing Tablet-PC-based presentation system, Classroom Presenter [1], which supports student wireless submission of digital ink answers to in-class exercises. Using Classroom Presenter, an instructor lectures and annotates slides with digital ink. The slides and ink are displayed simultaneously on a large screen and on students' Tablet PCs. When an instructor displays a slide containing an exercise, the students work the exercise, then anonymously submit digital ink answers to the instructor via a wireless network. Using Classroom Presenter in this way works well in classes of size eight or smaller, as instructors can be easily overwhelmed by more than eight solutions [5]. CLP's aggregation component will enable Classroom Presenter-like systems to be used in significantly larger classes.

With Classroom Presenter, and by extension CLP, instructor and students will interact more often and in a more meaningful way than has been possible to date. They will interact using a teaching technique that increases student learning by: (1) increasing student focus and attentiveness in class, (2) providing immediate feedback to both students and instructor about student misunderstandings, (3) enabling the instructor to adjust course material in real-time based upon student answers to in-class exercises, (4) increasing student satisfaction. The studies described in this paper investigate each of the above four parameters.

This paper summarizes results from a previous pilot study [6], and presents preliminary results from our current study.

CLASSROOM EXPERIMENTS

Shown in Figures 1 and 2 are examples of use of Classroom Presenter in MIT's introductory computer science course, 6.001, in Fall 2005 and Spring 2006. Students taking the course attend sessions five times weekly: two 50 minute lectures per week (taught by a faculty member), class size of between 100 and 300; two 50 minute recitations per week (taught by faculty members), class size of between 15 and 30; one 50 minute tutorial a week (taught by a graduate student teaching assistant), class size of five to seven. Lectures are the primary vehicle for introducing new material; recitations expand on the lecture material, allowing students to practice working with the material; and tutorials provide students with the opportunity to get individual help and further practice.

Student performance in 6.001 is assessed for the 15 week term by means of two exams and a final exam (each 25% of the course grade), five programming projects (30%), weekly problem sets submitted via an online tutor system (10%), and class participation in recitations and tutorials (10%).

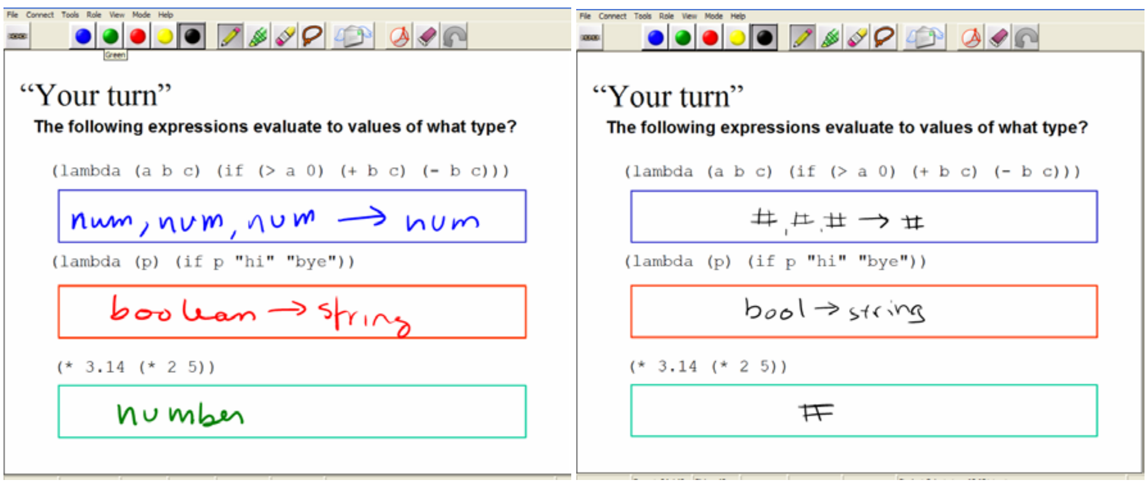

Figure 1. Two student screens with correct answers

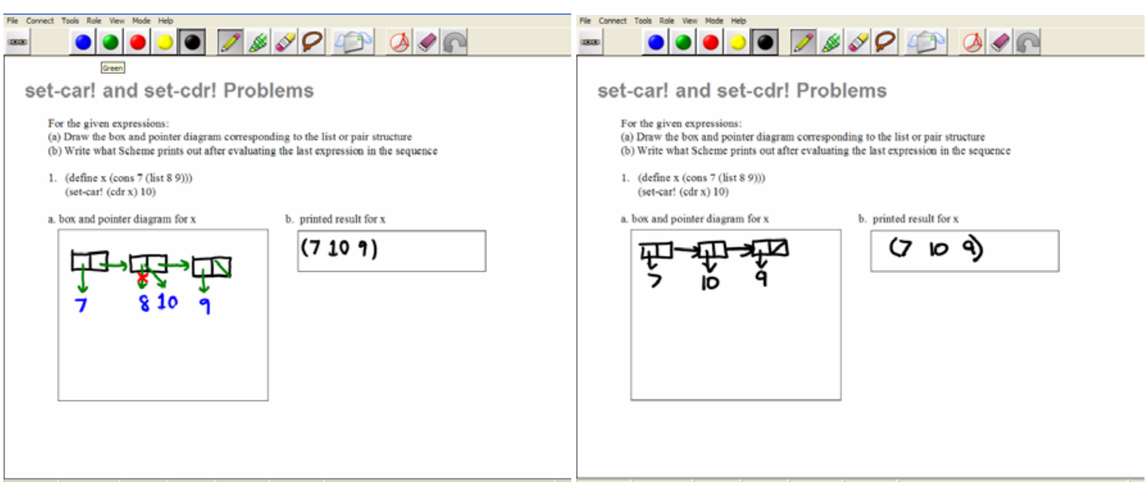

Figure 3. Two student screens with correct answers: left screen shows derivation of answer with "x" designating pointer removal

Fall 2005 Study

In the Fall term of 2005, Classroom Presenter was deployed in the first author's introductory computer science recitation class of 15 students. As noted earlier, the class met twice a week. Through classroom observation, surveys, and interviews by the second author, we investigated student focus and attentiveness in class, feedback to students and instructor, adjustment of course material by instructor, and student satisfaction. The methodology used was repeated in Spring term of 2006, with the addition of a control class in which students did not use Tablet PCs. The Fall study is summarized here and described in more detail in [ref wipte].

Methodology

1. Students were assigned randomly to the class, so that our sample would not be biased by containing students who might have a predilection for using Tablet PCs.

2. The Tablet PCs were associated with the class, not with each student, so that we could ensure machines would be loaded with the correct software versions and would not be forgotten or left uncharged.

3. After the first exam, fifth week our of fifteen, the instructor used Classroom Presenter; students wirelessly submitted answers to in-class exercises.

4. Three categories of data were collected: (1) two surveys, one given at the time the students began using Tablet PCs, the second at the end of the term; (2) multiple timed five-minute observation periods of students; and (3) short after-class interviews with students. The data collected related to the students' learning styles and preferences, self-perceptions, and levels of satisfaction.

5. Students saved their work directly to their campus directories.

Metrics

We assessed increase in student learning by collecting data on all grades for exams, programming projects, problem sets, the final examination, and class participation for the entire class of 100 students. The results for students in the pilot class were compared to results for students in the other four recitation classes.

In addition to investigating changes in student learning, Our study sought to quantify the following four parameters through classroom observation, surveys and interviews. (See [6] for more details.)

1. Student focus and attentiveness in class
2. Feedback to students and instructor about student misunderstandings
3. Adjustment in course material made by instructor:
4. Student satisfaction and self-perceptions

Results

The students in this class performed three times better than would be expected by chance: They comprised 15.3% of the entire computer science class, but 44.4% of students in the top 10% of the class in final grades—an 8.7% increase over performance on the first exam (prior to use of the Tablet PC) and three times greater than the expected 15.3%. The students also were much less apt to perform poorly: Only 8.3% of these students placed in the bottom 25% of the entire class. The expected percentage again was 15.3%. Further, no student received a D or an F. (In the entire class of 100 students, there were four Fs and three Ds, evenly distributed between the other two recitation instructors.)

Students were focused and attentive in class. There were only six observed incidents when students used their Tablet PCs for unrelated work. Of these incidents, two students who already knew the material did their computer science homework instead. The other students when interviewed indicated that they read their email or surfed the web because they felt behind in the class and could not follow the material being presented.

Seventy-five percent of the class time was spent providing feedback to students in response to written answers submitted to exercises and verbal questions related to the exercises. All students whose grades placed them in the middle third of the class reported that feedback helped them. The top third of students primarily benefited only on the relatively few problems on which they had difficulty. The bottom third also benefited but often felt that they needed more time spent on the answers that they did not understand.

The instructor placed emphasis on responding to student misunderstandings, which were evident from incorrect submitted answers or oral questions. She postponed introduction of new in-class exercises in three of thirteen recitations in order to spend more time on misunderstood concepts. In two recitations, the instructor introduced new, more challenging exercises because all submitted answers to preplanned exercises were correct. The instructor, thus, presented both preplanned and extra exercises, while also responding to all student questions.

Student satisfaction was extremely high, but can be more precisely analyzed when based upon level of performance in class. The top third of the students perceived the computer science course to be much easier than anticipated because they were able to get immediate feedback in recitation on the few questions that caused them difficulty. The three students who felt that they did not benefit from the use of the Tablet PC had the bottom three grades in the class. (These students may have benefited, however, since their grades were 1 B and 2 Cs.)

In summary, our results indicate that student learning seems to be positively affected by the use of engagement strategies, the Tablet PC, and the Classroom Presenter software. The feedback mechanism in particular seems to have been beneficial, resulting in fewer students than expected performing poorly. The study sample size was small, however, and there was no control group, so several more Tablet PC deployments are planned that incorporate what we have learned from this initial study. In the next section, we describe our follow-up study.

Spring 2006 Study

In Spring term of 2006, we ran another study using Classroom Presenter in two introductory computer science classes, one of which serves as a control group: The first author is teaching one class with Tablet PCs, one without. This study is following the same methodology as the Fall 2005 study, but with the added control group and with the ability to count individual student submissions as a measure of interaction.[1] We currently are analyzing results from the study and again anticipate that use of the Tablet PC system may result in fewer students performing poorly. We suggest that the Tablet PC system enables students who might otherwise struggle, to have additional means by which to understand the material and correct mistakes. Feedback and the opportunity to redo incorrect responses would seem to be effective as a means of improving their learning. Those students who would do well without the Tablet PC system, also may increase their understanding even more.

Preliminary results

Preliminary analysis of exam grades for Tablet-PC and non-Tablet-PC students seems to support the positive effect of the combination of teaching style, Classroom Presenter, and Tablet PCs on poorer performing students.

There was no significant difference in performance among students in the two classes prior to deployment of the Tablet PC: The mean score on the first exam was 76.4 (out of 100) for the non-Tablet-PC students (N=19), and 80 for the soon-to-be-Tablet-PC students (N=19)—a difference of 3.6. Both scores were considered Bs. The mean for the entire class was 75.0 (N=239).

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[1] A submission is anonymous in that it does not contain the student's name, but rather the machine's name. A mapping of student name to machine name is made when students log in at the beginning of class, but is only used by the second author in relating classroom interaction with performance.

The second exam performance showed a slightly larger difference, of 6.8, between the groups: The mean for non-Tablet-PC students was 78.5 (N=18); for Tablet-PC users it was 85.3 (N=18).[2] The mean for the entire class was 74.5 (N=227). While the difference in exam 2 performance is not statistically significant because of a small N, it is nevertheless worth noting that the mean for the Tablet-PC class increased 10.8% and into the A range.

Slightly more students performed in the top 25% in the Tablet-PC class than in the non-Tablet-PC class: 43.8% of the Tablet-PC class, vs 35.3%; expected value in each case based on normal distribution was 25%.

Perhaps more importantly, however, fewer students than expected did poorly on the second exam in the Tablet-PC class: 23.5% of non-Tablet-PC students were in the bottom 25% of the class, vs 6.0%. Again, the expected value in each case was 25%. It appears then that only one quarter as many students as expected performed poorly in the Tablet-PC class.

We were able this term to collect data about student submissions. Our preliminary results indicate that those students who gave an average of 3.5 answers per class or higher averaged 89.6% on the second exam. (There were on average three or four problems per class.) Those students who gave an average of 1.1 answers or less per class averaged 75.5% on the second exam. There were more than four times as many correct answers as incorrect answers. Around fifteen percent of the submissions were resubmissions, evenly split between students correcting an error that they discovered in their first answers and students offering a more elaborate or alternate solution. Although N was too small to establish statistical significance, the increase by 14.1% in the second exam results is a possible indication that active involvement in the class through working in-class exercises using Classroom Presenter and the Tablet PC contributed to learning of the course material.

Contributions and Current Work

In the two studies reported in this paper, we evaluate the hypothesis that the use of a Tablet-PC-based classroom presentation system such as Classroom Presenter increases student learning by: (1) increasing student focus and attentiveness in class, (2) providing immediate feedback to both students and instructor about student misunderstandings, (3) enabling the instructor to adjust course material in real-time based upon student answers to in-class exercises, (4) increasing student satisfaction. Our preliminary results seem to indicate that this hypothesis holds true, and that use of the Classroom Presenter and the Tablet PC may be directly responsible for an increase in performance of students taking introductory computer science. We are particularly struck by the increase in performance of those students who might otherwise have done poorly. This research effort contributes to the widely accepted pedagogy that feedback contributes significantly to student learning. This pedagogy is both practical and

[2] One student in each of the two recitations in the study dropped the course.

possible through in-class assessment using Classroom Presenter and Tablet PCs.

We plan to continue our analysis of the current experiment and design new experiments for the academic year 2006 and 2007. In particular, because of the small number of students involved in these initial research efforts, we plan to repeat the experiments with a larger number of students. In addition, we will focus effort on the quality and quantity of the responses that students make when using Classroom Presenter and the Tablet PC.

Finally, we plan to deploy Classroom Learning Partner, which adds ink interpretation and aggregation components to Classroom Presenter, and evaluate its use in 6.001 recitations next year. If we can validate our initial findings and replicate the results, then we will be in a position to introduce these pedagogies into much larger classrooms in the very near future.

Acknowledgments

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