Abstract - Programming skills are in increasing demand in nearly all disciplines. To cater to this demand the Computer Sciences department, at our institution, offers programming courses tailored for non-majors. Historically, we have observed the highest drop rate in the introductory course even though most of the students have had some prior experience with computers. Course evaluations indicate that most of them feel that programming is a challenging intellectual exercise. To allay student concerns we decided to apply Active Learning techniques in the lectures as well as in the discussion sessions. We wanted to give students feedback on their understanding of the lecture material during the class period and thereby reinforce their learning process. We also wanted some insight on how well the lecture material was being assimilated. For these purposes we used the Classroom Performance System (CPS), which is a software/hardware system that allowed us to pose multiple choice questions during lectures and receive responses from students through their hand held remote control pads. The system tallied and recorded the responses and displayed the results in histograms. The correct answer was highlighted for students to get immediate feedback on their performance compared to their peers. We measured the effectiveness of this approach through student surveys, student ratings, classroom observations, CPS results, and analyses of the students' performance on the final examination. Student experience was largely positive and most students reported that this Active Learning technique helped them understand new and difficult material. From the instructor's perspective this new approach provided us with a better gauge to student understanding and kept students engaged during the lectures.

Index Terms – active learning, classroom performance system, interactive technology, introductory programming.

JUSTIFICATION

CS 303E is the first course in the Elements of Computing series offered by the Computer Sciences department at the University of Texas at Austin. The Elements of Computing is a program for non-CS students. Students get a certificate when they complete four courses in this series. There are two required courses and two elective courses for the certificate. CS 303E is one of the required courses. The Elements program is open to all students in the University but typically students in the Sciences and Engineering enroll.

In CS 303E, students are introduced to computer organization and basic computer programming using Java as the programming language. Enrollment in this course is high compared to the introductory course for CS majors. Students enter with high expectations about their grade in the course but as the semester progresses a large percentage of the students drop this class. The drop rate is significant enough to be a matter of concern and worry. Most students who drop view programming as being too challenging or time consuming. Since this is one of the foundation courses in the Elements of Computing series we would like to retain a larger percentage of the students without compromising our standards.

We decided to try Active Learning techniques in our classroom teaching to motivate and engage students in the learning process during the lectures. For that purpose we used a wireless interactive response system. The primary research questions in this study are: does Active Learning techniques increase student engagement, facilitate learning, and contribute to the progress of students in this course.

BACKGROUND

Active Learning is not a new technique. However, its advocacy for teaching at the college level has increased dramatically in recent years [1][2][3][4][5][6][7]. Early childhood researcher, Jean Piaget, demonstrated in the early 1900s that children learn better if they are led through a series of activities rather than just presented with facts [8][9][10][11][12]. The most contemporary view of learning is that people construct new knowledge and understanding based on what they already know and believe [13][14][15]. Instructors who have adopted the Active Learning process...
recognize that learning takes place when students make an effort to process new material.

Students master course material when they are able to summarize information, connect it to existing information, put the ideas in their own words, and use the information in a real context or in the solution of a problem. The mastery, which corresponds to achievement of the higher levels in Bloom's taxonomy of educational objectives - application, analysis, synthesis, and evaluation - is not achieved through traditional lectures [16]. To achieve these higher objectives, students should be challenged in a variety of ways, such as through direct questions and discussion, and through ways that allow them to collaboratively research and solve problems.

Numerous instructors have tried Active Learning techniques with positive results [17][18][19]. These instructors found that not only did the students perform well in the examinations but the class attendance was also higher. We applied this principle by interspersing lectures with multiple choice questions. Students and instructors gained valuable feedback when their electronic responses were immediately displayed. The resulting discussion and active engagement contributed to mastering the material and are the subjects of this study.

**Methodology**

This research involved forty-four students enrolled in an eleven-week CS 303E course in summer 2004 at UT Austin. The course consisted of a lecture two times a week given by the instructor and a discussion session once a week led by the teaching assistant.

There are several technologies that promote Active Learning in the classroom [20][21][22][23][24]. The technology chosen to engage our students in the Active Learning process was the Classroom Performance System (CPS) [23][25]. This technology had been successfully used by one of the authors for teaching a short introductory programming course [26]. That experience encouraged us to try this technology in a full-length course. The CPS is a software/hardware system that allows instructors to get instant feedback from students, using remote control devices and a portable receiver connected to a computer and software system. Students were given a wireless response pad that they used to respond to multiple-choice, true-false, and other closed-ended type questions. In about half of the lecture class sessions the CPS was used to administer review questions and to provide feedback on the correct answer and on the performance of the class as a whole. In the other half of the lecture class sessions review questions were administered via paper with only the correct answer provided as feedback. The teaching assistant used the CPS during most of the discussion sessions.

The main advantage of using the CPS in the Active Learning process was that it provided instant feedback to the instructor about what the students do and do not understand. The system also provided instant feedback to the students through a discussion of the correct response and a summary of the results of how the class did as a whole. To investigate the research questions several data collection methods were used such as classroom observations, student surveys, student rating scale, a student focus group, analysis of minute papers, analysis of CPS performance, and analysis of final exam performance.

Two observers conducted classroom observations of the lecture and discussion sessions during the fifth through the eighth weeks of the course. Classroom observations were conducted to record the general behavior of the class including recording student behavior at specific time points throughout the class, recording the types of questions asked by the students and the types of questions that were asked by the instructor. These observations were also classified according to whether or not the CPS was used during the session.

During the first week of lectures, the students filled out a pre-course survey assessing their expectations of engaging in various activities in order to perform well in the course. The questions were taken from the Metacognition and Self-Efficacy scales of the Motivation for Strategies Learning Questionnaire or MSLQ [27][28]. MSLQ is a self-report instrument designed to assess learning motivations and strategies of college students. The Metacognition scale measures the strategies students use to monitor their understanding of the course material. The Self-Efficacy scale assesses students' beliefs about their skills to be successful in the course. Students were asked to rate how true each statement was of them responding on a seven-point scale from 1 = "Not at all true of me" to 7 = "Very true of me". The same questions were used on a post-course survey during the last week of lectures. The Self-Efficacy scale total score is the sum of possible responses (1 to 7) for the eight scale items and ranges from 8 to 56. The Metacognition scale total score is the sum of possible responses (1 to 7) for the twelve scale items and ranges from 12 to 84. Additional questions on the post-course survey involved gathering information about the students' feelings toward the use of the CPS in the lectures and in the discussion sessions.

In addition to completing the two surveys, students were asked one rating question at the beginning and end of each class session. Students were asked to reflect on how confident they were about their understanding of the upcoming lesson and then how accurate they were in their prediction. Also after each lecture, the students were asked to write down any remaining questions they had from the day's lecture, known as a "minute paper". This eventually became a way for students to not only write down questions, but express concerns and criticisms they had about the material and pace of the lecture.

A focus group was organized during the eighth week of class to gather additional information from students about their experiences with the CPS. Five students, three females and two males, were recruited to participate in the focus group with the incentive of a free lunch.

Student content knowledge was measured through performance on the CPS questions as well as on the final exam. The final exam questions were coded as to whether or not they related to a topic that was presented using CPS.
RESULTS

Classroom Observations

The results from classroom observations show that for both types of days, CPS and Paper, students in general appeared attentive throughout the lecture with observed individual inattentiveness sometimes beginning 30 to 40 minutes into the 75-minute lecture. A high level of attentiveness (number of students writing notes about the exercise(s)) was observed when a specific problem was being explained on the chalkboard or when the students were working through a problem, regardless of whether or not the CPS was used.

Student Surveys

A two-tailed t-test for dependent means was performed to examine the mean differences between students’ total scores on questions from the pre- and post-course survey on attitudes and activities that they may engage in while in the course. This statistical test is used to determine whether differences from the beginning of the semester to the end of the semester occurred by chance. The test is two-tailed in that it examines changes in either a positive or negative direction whereas a one-tailed test would examine a change in one particular direction (e.g., that there would be a change from pre- to post-course survey). In most cases, statistical tests are two-tailed unless an a priori hypothesis has been made about the direction of the change.

A significance level, or p value, indicates the probability that differences from pre to post survey occurred by chance. The degrees of freedom, df, is one less than the total number of students who had pre and post course survey results and is used to determine how big the t-test value must be in order for the mean difference to be considered statistically significant.

Specifically, differences in the Metacognition and Self-Efficacy scales were examined from the beginning of the semester to the end. According to our analysis, there was a significant difference, at the 0.05 level, in Metacognition and Self-Efficacy between the beginning and conclusion of the course in that both scales decreased in total score. This total score decrease indicates that, on average, students engaged in fewer metacognitive strategies and were less confident in their abilities to do well at the end of the semester. Refer to Table I for descriptive statistics and Table II for t-test results.

Examining specific items on the Metacognition scale revealed that two questions had a significant difference between the pre- and post-course surveys:

- I plan to try to think through a topic and decide what I am supposed to learn from it rather than just reading it over when studying for this course.
- If I get confused taking notes in class, I plan to make sure I sort it out afterwards.

The mean difference for the first question was a decrease of 0.880 that produced a t(24) = 2.240 and p = .035, while the mean difference of the second question was a decrease of 1.400 that produced a t(24) = 3.742 and p = .001. Therefore, the probability was less than 4% that the approximately one point decrease (0.880) from the beginning to the end of class on the first Metacognition question occurred by chance. Likewise, the probability was 0.1% that the 1.40 point decrease from the beginning to the end of class on the second Metacognition question was due to chance.

The significant differences shown here could aid in explaining the overall decrease in Metacognition from the pre-and post-course surveys of a 6.50 decrease. Overall, students reported at the end of the semester they used fewer Metacognitive strategies than they had predicted at the beginning of the semester. In particular, they were less likely to think through topics when reading for the course and less likely to sort through their notes when confused.

Examining specific items from the self-efficacy scale showed that one question had a significant difference between the pre- and post-course surveys:

- Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.

The mean difference of this question was a decrease of 1.080 that produced a t(24) = 2.877 and p = .009. As with the Metacognition scale, this difference could help explain the overall decrease in Self-Efficacy of a 3.83 decrease. Therefore, the probability was near 0% that the one point decrease from the beginning to the end of class on the Self-efficacy question occurred by chance. In other words, students were less confident in their ability to do well in the class at the end of the semester.

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Focus Group

Several themes emerged from studying the transcript of the focus group. One such theme was that the CPS was very helpful in terms of its immediate feedback and anonymity. Not only did the CPS let the students know whether they got a particular question right, it also allowed them to see how they compared to the rest of the class. Also, the students felt less pressure when answering questions posed by the instructor (through the CPS) since the responses were anonymous at least from the rest of the class. Along with this, the CPS appeared most useful when explanations were provided along with the answers, and not just having the answers flashed on the screen.

Another major theme from the focus group was that the CPS used in discussion session was not very helpful since it was used primarily as a quizzing tool instead of a learning tool. This was similar to the survey results regarding students' perceptions of the use of the CPS in the lectures and the discussion sessions.

Student Minute Papers

In analyzing the "minute papers", it seems clear that the lectures did help a certain group of students understand the material better, especially those that had already read through the material. On the other hand, for another group it appears that the lectures did not help the students and sometimes appeared to make things worse for certain individuals.

CPS Individual Performance

Analyses of individual performance using the CPS were conducted. On specified days, in lecture and in discussion, students were presented a series of questions as review for the material they had recently covered in class or read in their texts. Typically, the number of questions ranged from two to six on a given day. Based on the percentage of correct responses for each day by each individual student, the mean percentage correct was computed for each day. There were ten days that this analysis covers. Students generally did not score better than 50% correct on review questions posed through the CPS. This finding appeared from the third day of CPS usage to the end of the semester. Refer to Table III for descriptive statistics of CPS performance. Row CPS4 refers to an optional discussion session and hence the low student turnout.

A correlation measures the amount of relationship between two variables, specifically whether as one variable changes does the other change in a consistent manner. The correlation between the mean CPS scores and final exam scores was .116, a non-significant correlation. The significance level indicates the probability that the two variables change together occurs by chance. Typically, a significance value, or p value, of .05 is used as the maximum probability to consider a correlation significant. Since the correlation between mean final exam scores and CPS scores was small and the significance level was greater than .05, there is no discernable relationship between students’ overall performance on the final exam and performance on the CPS questions. Refer to Table IV for correlation analysis results.

Final Exam Performance

For this analysis the questions on the final exam were coded as either related or not related to CPS review questions. An overall percentage score was computed for both groups of questions and used for comparisons. A t-test was conducted to determine if there was a significant difference in the overall performance on the final exam between CPS related questions and non CPS related questions. The results indicate the mean percentage on the questions from CPS-tested topics was 77.68 while the mean percentage from the other questions was 88.26, resulting in a significant difference of t(22) = 3.982 and p = .001. Refer to Table V for descriptive statistics and Table VI for t-test results.

DESCRIPTIVE STATISTICS FOR CPS AND NON-CPS RELATED FINAL EXAM ITEMS

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair CPS</td>
<td>77.68</td>
<td>23</td>
<td>14.5013</td>
<td>3.0237</td>
</tr>
<tr>
<td>NonCPS</td>
<td>88.26</td>
<td>23</td>
<td>10.2090</td>
<td>2.1287</td>
</tr>
</tbody>
</table>

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Table III

DESCRIPTIVE STATISTICS FOR CPS SCORES BY CLASS SESSION

<table>
<thead>
<tr>
<th>CPS</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPS1</td>
<td>20</td>
<td>51.00</td>
<td>27.891</td>
<td>6.237</td>
</tr>
<tr>
<td>CPS2</td>
<td>21</td>
<td>57.19</td>
<td>33.668</td>
<td>7.347</td>
</tr>
<tr>
<td>CPS3</td>
<td>20</td>
<td>27.50</td>
<td>22.798</td>
<td>5.098</td>
</tr>
<tr>
<td>CPS4</td>
<td>3</td>
<td>11.00</td>
<td>19.053</td>
<td>11.000</td>
</tr>
<tr>
<td>CPS5</td>
<td>22</td>
<td>24.18</td>
<td>32.840</td>
<td>5.101</td>
</tr>
<tr>
<td>CPS6</td>
<td>23</td>
<td>32.57</td>
<td>16.981</td>
<td>6.351</td>
</tr>
<tr>
<td>CPS7</td>
<td>22</td>
<td>49.95</td>
<td>24.872</td>
<td>5.303</td>
</tr>
<tr>
<td>CPS8</td>
<td>21</td>
<td>31.67</td>
<td>28.895</td>
<td>6.305</td>
</tr>
<tr>
<td>CPS9</td>
<td>20</td>
<td>30.00</td>
<td>29.912</td>
<td>6.689</td>
</tr>
<tr>
<td>CPS10</td>
<td>18</td>
<td>11.11</td>
<td>21.390</td>
<td>5.042</td>
</tr>
</tbody>
</table>

TABLE VI

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>Pair 1 CPS – Non CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference</td>
<td>10.5797</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>12.7412</td>
</tr>
<tr>
<td>Std. Error Mean</td>
<td>2.6567</td>
</tr>
<tr>
<td>95% Confidence Interval of Difference Lower</td>
<td>-16.0894</td>
</tr>
<tr>
<td>95% Confidence Interval of Difference Upper</td>
<td>5.0700</td>
</tr>
<tr>
<td>t</td>
<td>-3.982</td>
</tr>
<tr>
<td>df (degrees of freedom)</td>
<td>22</td>
</tr>
<tr>
<td>Sig (2-tailed)</td>
<td>.001</td>
</tr>
</tbody>
</table>

ASSESSMENT

The use of the CPS as an Active Learning tool has been positive. We found that the students were more attentive throughout the lectures when the CPS was being used because they anticipated questions on that material. Additionally, the CPS allowed everyone to participate instead of a vocal few. The relative anonymity of the CPS responses took the pressure of shy students. Students felt that the discussion that followed each question helped them understand the material better.

However, introducing Active Learning techniques in lectures puts more responsibility on both instructors and students. For instructors the preparation time is significantly more. Questions have to be chosen with care and solutions should appear reasonable. Students have to think through all the choices and this exercise increases their analytical skills. To really benefit from this process, students have the responsibility of coming to class having completed the assigned reading. Merely guessing the solution and listening to the discussion on the correct choice reverts back to passive learning.

In this study, the CPS scores were not counted for the final grade for the course. We had intended that the students' responses should be pressure free. Students generally did not perform better than 50% correct on the CPS questions. In hindsight, it appears that we should have made the CPS scores count towards a small fraction of the overall grade. This would have provided sufficient incentive for the students to study and put some effort in thinking through all the choices and then answering the questions instead of just guessing.

On the final exam students did better on the questions that were not covered by the CPS review. This finding should be interpreted with caution. The CPS related questions covered some of the more difficult topics compared with the non CPS related questions. The final exam questions were not selected to be at the same level of difficulty.

Students entered the course with high expectation about their performance and a strong belief that they would monitor their learning and adjust accordingly. By the end of the semester, students were less confident in their skills and engaged less in monitoring than they predicted at the beginning of the semester. Students may have underestimated the difficulty of the course content and/or the work required to understand the material. All of them had some form of computer experience through word processing and internet access. Some had prior programming experience and/or were familiar with common hardware terms. However, students who did well on the course did not necessarily have previous programming background. They had good logical skills and the discipline to do the assigned reading and work. Students who did well on the CPS questions also did well on the final exam.

CONCLUSIONS

The results presented here provide a solid first step in analyzing the efficacy of the technologies that support Active Learning like Classroom Performance System as an Active Learning tool. There are several unanswered questions that should be addressed through further research. Would including the students' scores on the CPS questions in the estimation of the overall grade be an incentive for students to be more involved in the Active Learning process? The types of questions suitable for Active Learning using CPS should be researched. Retention was not addressed in this study but it is certainly an important issue in computer science. By using Active Learning techniques, beginning programming becomes easier and more enjoyable for the students. Would that cause a higher retention rate? These questions should be discussed and researched. Their answers will provide a greater understanding of the Active Learning techniques and the use of the CPS as a learning tool in the early stage of computer science education.

ACKNOWLEDGMENT

We want to thank Marilla Svinicki for her pedagogical support in designing this project. We gratefully acknowledge Lynn Eaton’s contribution to our discussion on Active Learning. We thank the staff at the Division of Instructional Innovation and Assessment for providing technical help with the CPS system and the Measurement and Evaluation Center for their support in collecting and analyzing the data. But most importantly we would like to thank the students for their participation in this study.

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