Combining Cooperative Learning And Peer Instruction In Introductory Computer Science

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Abstract

CPSC 120, Principles of Computer Science I, is a first semester freshmen level course for computer science majors. Over a three semester comparison period, this course had an average WDF rate of 56% (i.e. percentage of students receiving a grade of "D" or "F", or withdrawing from the course). In two sections of this course, two strategies, peer instruction and cooperative learning, were combined to lower the WDF rate for both sections to an average of 32.5%. The improvement was even more dramatic for the female students in the classes, who improved from a 53% WDF rate to a WDF rate of only 15%.

Keywords

Cooperative Learning, Peer Instruction, Retention, Persistence.

1 Introduction

CPSC 120, Principles of Computer Science I, is the first course for computer science majors. Like many courses in the sciences, this course typically has a high WDF rate (i.e. percentage of students receiving a grade of "D" or "F", or withdrawing from the course). To address this problem we have used two strategies, peer instruction, the use of undergraduate student co-teachers, and cooperative learning, the use of student peer groups organized as learning environments. This paper describes our experience with combining these strategies to lower the WDF rate in selected sections of this course.

Radford University is a medium size, comprehensive university, located in the mountains of southwest Virginia. The Computer Science B.S. program is CSAB accredited and has approximately 175 majors. This number includes a large number of freshmen, and, as is the case with many Computer Science programs, this number has risen dramatically in recent years. Students in the program take a traditional CS1/CS2 sequence in their freshmen year. Although the department offers an interdisciplinary master’s degree in computational science, the graduate students in this program do not assist the department in offering the undergraduate major.

2 CPSC 120

CPSC 120 is a four credit hour course that meets three hours per week in lecture and two hours per week in a closed laboratory. Each section of the course is limited to approximately 30 students due to the size of the lab. As an introduction to the major, CPSC 120 seeks to introduce students to a disciplined and rigorous approach to the programming and problem solving process. To master this process and to gain needed programming skills, students in the course typically submit about 12 programs during a 15 week semester. Half of these assignments are completed during the closed lab sessions and the rest are done independently outside of lab. Students may also complete analysis and design documents for some of the programming projects.
In addition to the programming assignments, assessment of students in CPSC 120 usually includes 3 in-class exams, and a variety of quizzes and in-class assignments. For the two sections which are the topic of this paper, the weighting of these assessment measures was:

- 3 examinations (20% each) 60%
- 6 programming assignments 30%
- quizzes and laboratory assignments 10%

Although CPSC 120 serves as an introduction to the computer science major, many students who take the course are not freshmen and many are not computer science majors. The mathematics and information systems programs both require CPSC 120, and at times a large majority of the students in a section of CPSC 120 are from these and other majors.

3 Study Sections and Comparison Period

The two sections of CPSC 120 that are the subject of this case study were offered in the Fall 1997 and Spring 1999 semesters. The Spring and Fall 1998 semesters are not included in this study. Spring 1998 was excluded because the only professor using the cooperative learning strategy did not teach CPSC 120 that semester. Fall 1998 was excluded because staffing problems made it impossible to recreate the desired learning environment in these sections. The two sections, Fall 1997 and Spring 1999, that implemented both peer instruction and cooperative learning are the subject of this case study and hereafter are called the study sections.

As a basis for comparison with these study sections, data was gathered from all sections of CPSC 120 during the three semesters prior to Fall 1997, that is from Spring 1996 through Spring 1997, inclusive. For the ten sections of CPSC 120 offered during this comparison period, the WDF rate for all 262 students enrolled was 56%. These three semesters were selected for comparison because a major curriculum revision, a language change from Pascal to Ada 95, had been implemented the previous semester (i.e. Fall 1995). Prior to this comparison period the WDF rate had also been quite high, frequently exceeding 50%.

4 Peer Instruction

In searching for ways to lower the WDF rate, we first looked for successful techniques that were being used in other programs within the university. One such program is University 100 (UNIV 100), a freshmen orientation course in which an undergraduate peer instructor (PI) serves as a co-teacher. Each PI joins with either a regular faculty member, a member of the administration, or a member of the university staff to form a team that teaches one 25-student section of the course. Students attend UNIV 100 twice per week for twelve weeks and earn one semester hour of credit for the course. The peer instructors help plan and deliver course presentations, help administer the course, and hold one office hour per week to respond to student questions or concerns. After the first three years of this course, the university’s freshmen retention rate improved from 68% to 75% and has remained at that level. Much of this success in freshmen retention is attributed to UNIV 100.

The success of University 100 suggested that peer instruction could be an effective technique for decreasing the WDF rate in CPSC 120, and in Fall 1997, four peer instructors were hired to co-teach the four sections of CPSC 120 that we offered that semester. In tailoring this program to CPSC 120, we developed the following model for using the peer instructors:

- Only students who had recently and successfully completed CPSC 120 were hired as PI’s.
- Each PI was assigned to a single section of CPSC 120.
- Each PI worked three hours per week: one hour holding office hours and two hours assisting in the closed lab sessions.
- Unlike the UNIV100 model, the PI’s did not normally present material in lecture or lab, although occasionally a PI would act as a substitute lecturer or hold a help session.
- Each peer instructor met with his or her assigned co-teacher regularly (in most cases, weekly) to discuss course material and student progress.

Most of the PI’s were computer science majors although some were mathematics or information systems majors. We had hoped to use only computer science majors, however, the abundance of jobs for computer science majors in the local market made it difficult to find PI’s.

The peer instructors for CPSC 120 participated in a training session that included:

- techniques for leading students to answers instead of giving them answers,
- discussions of sexual harassment and related issues,
• discussions regarding safety (the majority of the peer instructors were female), and
• discussions of academic integrity and the honor system since peer instructors would be in a position to observe cheating.

5 Cooperative Learning

While studying peer instruction, we also learned of research and literature surrounding cooperative learning (e.g. Johnson, Johnson, and Smith [2]). Cooperative learning is an education strategy that uses student peer groups as orchestrated learning environments. Group work has long been an important component of computer science education since it models the way software development is done in industry. However cooperative learning involves manipulating groups into planned cooperative learning environments which is relatively new and uncommon in our discipline. Some previous work using cooperative learning in computer science (e.g. Walker [6], Tenenberg [5]) gave us ideas on how to integrate cooperative learning into a computer science classroom. The results of this previous work led us to expect that the use of cooperative learning would improve the WDF rate and, as Walker [6] predicted, that it could provide more benefit to female students. Consequently, in the Fall of 1997, we implemented this approach in a single section of CPSCI20. We had good success in this section[1] and were eager to continue using these strategies in another section of the course. However, as described above, we were not able to implement this combination of strategies again until Spring 1999.

6 Implementing the Strategies

While we expected the students to benefit from the use of these strategies, we recognized, as cautioned by Walker [6] that "the change from a traditional lecture/separate lab version of CS1 to the collaborative learning approach requires a significant rethinking of the course and adjustments, especially for faculty." In order to facilitate this reorganization, we first focussed on our goals for the students in the course:

• More student time on task
• Higher level of commitment from students toward the course
• Reduced levels of student frustration, especially in the beginning of the course
• Better, and earlier, student understanding of topics presented in course

We then set about organizing the class to use peer instruction and cooperative learning to accomplish these goals.

The first week of CPSC 120 typically involves a great deal of time spent orienting the students to computer systems that are new to virtually all of them (i.e. Sun workstations and the UNIX operating system, editors, and compilers). The goal of this first week is to bring students up to speed quickly so that they will not be hampered by these new tools as they work to master more difficult concepts. The peer instructor played a major role in this first week since their presence meant that questions were answered more quickly. This not only allowed the students to accomplish more in each lab session, but also reduced student frustration, a major contributing factor to student withdrawal [4]. Also during this first week, in a foreshadowing of the cooperative groups that would be formed the following week, the instructor encouraged students who understood a topic to help those that did not. In this way, the "Aha!" experience was communicated and shared in a way that a single instructor probably could not and students again were able to accomplish more with less frustration. As a method of forming a community of learners and thus fostering more commitment to the course, active learning exercises were used in the first week to increase student familiarity and comfort with each other. These included everything from name games to team building exercises.

At the beginning of the second week of classes, once the roster had stabilized, the class was divided into cooperative groups. To accomplish this, students first took a short in-class psychological profile based on work by Keirsey and Bates [3]. The results of this profile allowed the instructor to build four person groups that had a mixture personality types. Lecture time was also taken to discuss group roles with the class so that they might be aware of the various roles they would need to take on throughout the semester (e.g. leader, facilitator, recorder, peacemaker).

Once groups were formed, each became responsible for its members. If someone missed a class, for example, it was the group's responsibility to keep the student engaged in the course. Students from the group would make sure that the student that missed was able to get a copy of the notes as well as any handouts or assignments. If a student went on to miss several days, then someone in the group would make contact and encourage the student to remain active in the class and in the group. These groups fostered more commitment from the students by involving them more closely with their classmates. They had the further
advantage of helping to reduce frustration as students could now ask their group members questions when neither the instructor nor the peer instructor were available.

A second primary means of using the cooperative groups was in the introduction of new topics to the students. Each new topic was first explained briefly in lecture, and then this introduction would be followed by a group assignment involving that topic. Lecture and laboratory time were allocated for these group projects and both instructor and peer instructor support were available. Once the group task had been completed, individual assignments were given on the same topic. To enhance individual learning and independence from the group, students could only get help on the individual projects from the instructor or the peer instructor. Closed laboratory time was allocated for work on individual projects to provide feedback to the students and to allow the instructor and the peer instructor to observe the progress of individual students. Using the groups in this way increased student time on task by allowing each student to first see a new topic in the classroom, then gain experience solving a related problem in a group setting, solve a similar problem independently, and finally be tested on the topic. The use of the groups in this manner also fostered better understanding of the topics in the course as students communicated their understanding to other students in ways that the instructors typically did not.

7 Results

The study sections yielded very noticeable changes in both the WDF rate and the grade distributions. In Fall 1997, the WDF rate for the study section was 32%, a 24 percentage point improvement over the rate during the comparison period. The WDF rate for the Spring 1999 section was 33%. As shown in Figure 1, however, the percentages of students receiving grades of "A" or "B" for both study sections were nearly identical to the comparison period values. From Figure 1, it is apparent that the net effect of the combination of the two strategies was to move some students from the WDF category to the "C" category.

As shown in Figure 2, the percentage of students receiving a grade of "F" for the course was reduced to roughly 3% (or 1 student out of 32 for Fall 1997 and 1 student out of 33 for Spring 99) for both of the study sections. The difference between the two study sections is in the "D" and "W" categories. The Fall 1997 section had roughly the same percentage of students in the "D" category as in the comparison period while the percentage in the "W" category was much smaller. The Spring 1999 section reversed this result with the percentage of students in the "W" category being similar to the comparison period value while the percentage in the "D" category was much smaller. We have provided a possible explanation of this reversal in the next section.

One interesting result not shown in the graphs was that the WDF rate among female students was only 18% in the first study section and only 12% in the second study section. In fact, this 12% result from the second study section represents 2 females (out of 16) that withdrew from the course and they both withdrew one day prior to the withdrawal date, twelve weeks into the course. These percentages are dramatically better than the 53% average WDF rate among female students during the comparison period. This is in agreement with Walker's [6] prediction that cooperative learning strategies would have more positive impact on female students.

Figure 1. Comparison of percentage of students receiving each letter grade in study sections and in comparison period, grouped by grade category.

Figure 2. Comparison of percentage of students receiving each letter grade in study sections and in comparison period.
8 Conclusions

Two conclusions can be drawn from the data in Figure 1. First, as demonstrated by the decreased WDF rate for both of the study sections, the combination of peer instruction with cooperative learning can improve the success of students in an introductory computer science course. Second, since there is no increase in the percentage of students receiving grades of either “A” or “B”, we can conclude that these strategies have more impact on weaker students.

The data in Figure 2 provide for two additional conclusions. First, fewer students received a grade of “F” for the course in the two study sections. This can best be explained by understanding how difficult it would be to come to class every day, participate in class, and then fail the class without realizing that you were going to fail the class by the withdrawal date in the 12th week of the semester. Students in these sections attended class more regularly and participated more actively in class discussions and activities. Second, the combination of these strategies encouraged students to persist in the course, perhaps to their detriment if the instructor was not careful. In the Fall 1997 study section, the percentage of students receiving grades of “D” was high, similar to that of the comparison period, while the “F” and “W” percentages were very low. By the time of the Spring 1999 study section, having analyzed the data from the previous study section, we realized the techniques we were using were doing such a good job of motivating persistence in the course that very weak students may need encouragement to withdraw rather than risk failing a 4 credit hour course. Therefore, students were warned that if their average was not a “C” or better by the 11th week of the semester, they needed to meet with the instructor to discuss their options. In this way, students with little hope of passing the course with a “C”, the grade required to continue in the major, were encouraged to withdraw. This change in strategy accounts for the difference in the grade distributions between the two study sections.

It is also clear that the combination of these two strategies, while providing positive results for most students, provided more positive results for female students in the course. The cause of this bias is not obvious, however, the bias has been previously noted [6] and tentatively explained for cooperative learning [2].

9 Future Work

Peer instruction has been used in CPSC 120 every semester since Fall 1997, and cooperative learning has been used several times since the original study section was offered. During this time, CPSC 120 has been offered in several other formats. Future work will involve studying this larger set of data. It will also involve refining the techniques used in cooperative learning and peer instruction to make these techniques even more effective.

Work is continuing, with the aid of researchers in sociology, to explain the positive bias of these techniques with female students. Understanding this bias might help us to refine other teaching strategies to achieve similar results.

References


