Studying the Use of Peer Learning in the Introductory Computer Science Curriculum*

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Abstract

This paper reports the results of studying the use of peer learning in the introductory computer science curriculum. The project involves educators from a variety of institutions who participated in two summer workshops and either introduced or continued their use of peer learning at their institutions as part of this project. The results of the collective work include much experience with different types of peer learning in different settings. Overall, the results indicate that peer learning is a valuable technique that should be used as one pedagogical approach in teaching the introductory computer science curriculum.

KEYWORDS: peer learning, cooperative learning, introductory computer science, computer science education
Abbreviated Title: "Peer Learning in Intro Computer Science"

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1 Introduction

This paper reports on the use of peer learning in the introductory computer science curriculum. It is the result of a two-year project to better utilize the potential of student interaction in the student learning process within the introductory computer science curriculum. We use the term peer learning to broadly include cooperative and collaborative learning. It involves students working together as part of their own learning experience. Peer learning can take many forms. It is often used in upper-level Computer Science courses and is routinely used in other disciplines and K-12 education. Excellent references for the use of cooperative learning in college teaching are available [1, 2, 3, 4, 6]. However, reports of its use and evaluation of its effectiveness in the introductory (freshman and sophomore) level computer science curriculum are limited [11, 13].

Our approach for examining and assessing this pedagogical technique for the introductory computer science curriculum has been to bring together a diversity of computer science educators for two workshops held in June 1996 and June 1997 on the campus of Worcester Polytechnic Institute (WPI). These workshops and the ensuing interactions initiated work on peer learning by participants at their own campuses.

As a result of this peer learning project, the participants have gained valuable experience in using different types of peer learning activities in different types of introductory computer science courses at different types of institutions. The paper does not attempt to describe these activities in depth, but summarizes what we have collectively learned from these experiences and what we believe is important to communicate to the larger computer science education community.

The paper begins by discussing the goals and methodology for the project. It goes on to discuss the results of what we have learned both in our workshop meetings and our respective uses of peer learning on each campus. The paper continues with a description of assessment activities and concludes with the lessons

learned and a summary of our work.

2 Project Goals

The peer learning project has a number of goals relating to peer learning that pertain directly to faculty in the computer science community and to the students taught by these faculty:

- Draw upon the expertise of faculty already actively engaged in the use of peer learning in the introductory computer science curriculum. Many approaches are being used for peer learning; we want to bring faculty together who have experience with different approaches.

- Expose faculty interested in, yet inexperienced with, peer learning to specific techniques and activities that could be used in the classroom. Workshop participants should be able to leave with activities that they can immediately use in the classroom.

- Develop instructional materials during the workshop that incorporate peer learning into the curriculum by grouping experienced and inexperienced faculty. Faculty use "peer learning" as they gain experience developing peer learning activities to be incorporated into their curricula.

- Assess this teaching approach and its impact on student learning. Assessment and evaluation of teaching effectiveness are essential.

- Disseminate the work to a wide audience. The results and activities of the workshops should be available not only to the participants, but to interested faculty at all schools.

A more general goal of this project is to make introductory computer science courses more accessible and relevant for students with a diversity of educational

and social backgrounds. In support of this goal, collaborative learning has been shown to increase both academic performance and persistence of new college students [2, 12]. Work by the National Science Foundation (NSF) supported Project Kaleidoscope suggests that "an active community of learners" with students working in small groups is the best learning situation for dealing with both majors and non-majors [7]. Peer learning also improves accessibility for minority students. A report on programs for retaining and helping minority students determined that the most important aspect of effective programs is a collaborative learning environment, which encourages students to become part of a social network [8].

3 Project Methodology

The approach used to carry out the goals of the project was to gather a diversity of educators from a cross-section of institutions for an ongoing collaboration initiated by an NSF-supported workshop in June 1996. The workshop not only brought together educators using peer learning in the introductory computer science curriculum, but also others who were interested in experimenting with this mode of teaching. We believe the use of peer collaboration among faculty is a natural approach to coordinate and disseminate work on peer learning.

Participants in the first workshop discussed the general strengths and weaknesses of peer learning and experienced participants explained how they used it in their classrooms. Based on this discussion, an important part of the workshop consisted of participants working together in small group settings and developing new peer learning tasks and activities that could be used at various institutions. These tasks were catalogued using a worksheet to record the various aspects of each task, such as objectives, group size, group formation, duration and grading criteria [16].

At the conclusion of the first workshop, participants returned to their institutions to continue or initiate the use of peer learning in their introductory computer

science curriculum. The participants also took with them techniques for assessing the effectiveness of the approach. Jim Groccia, Director, Program for Excellence in Teaching at the University of Missouri, served as consultant for the project to advise participants on the assessment component. More details on assessment are discussed in Section 5. The results from the first workshop and the specific activities of some participants were presented by a panel at the 1997 ACM SIGCSE conference [15].

The second year workshop included many of the first year workshop participants along with new participants. New participants brought with them situations within their curriculum in which they would like to use peer learning. As was done in the first workshop, these situations served as starting points for splitting into groups and developing peer learning activities appropriate for the situations.

The focus of the second year workshop was the presentation and discussion of the peer learning activities used by participants during the preceding year. These presentations about the activities and their assessment led to much discussion about what was learned from each activity and how each could be improved. Work continued at each respective institution following the second year workshop. Participants were surveyed at the end of that academic year as part of the final evaluation for the project.

In all, 12 participants attended the first workshop and 16 the second workshop with six of those participants attending both workshops. Table 1 provides additional information about the demographics of the participants (see [16] for a list of participants). In total the project attracted interest from 35 educators who either attended one of the workshops or expressed interest in the outcome. The curriculum changes introduced by the project participants affected hundreds of students at a variety of institutions.

Table 1: Workshop Participant Demographics

Workshop	Number of Participants	Gender		Institution Type	
		Female	Male	Private	Public
1996	12	6	6	3	9
1997	16	10	6	7	9
Total[a]	22	11	11	7	15

[a]Includes six faculty who participated in both workshops.

4 Results

The culmination of the second workshop was a discussion of lingering participant questions/concerns regarding peer learning and an initial discussion of what we learned from these activities and the overall project. These discussions continued as we returned to our respective campuses to continue our specific activities and reflect on them in the context of the project. The following presents the results of what we have learned based on these discussions and the final project evaluation. These results encompass specific work published by project participants [5, 9, 10, 18].

4.1 Types of Peer Learning Tasks

One of the results from the first workshop was the observation that the tasks being used and developed by participants can be broadly categorized based on two characteristics of the tasks—the objective and the setting. Table 2 shows that peer learning tasks can be used in a class, in a laboratory setting or as part of an out-of-class project. The rows show the range of objectives for such a task. Get acquainted tasks can be used as "ice-breakers" among students as a precursor to other cooperative tasks. Simple cooperative tasks can be done on an informal basis where students work together to discuss a topic. A more organized cooperative task might end with a specific result that is shared with others, but the result is either not graded or only graded on participation. Finally, a larger scale exercise has a result that constitutes a non-trivial portion of the participants' grades.

Table 2: Cooperative Task Characterization

	Duration/Setting		
Purpose/Objective	In-Class	In-Lab	Out-of-Class
Get Acquainted	x		
Informal Discussion	x		
Result/Non-Graded	x	x	
Result/Graded	x	x	x

Table 2 shows the various combinations of these two characteristics in the tasks developed and used by project participants. A total of 29 such tasks are described and catalogued in [16]. This characterization provides guidelines to others as to the types of tasks that are appropriate to use in various settings. The results show that the entire range of tasks is used in a class, but that out-of-class projects, which often involve more time, are typically graded.

In addition to identifying different types of peer learning tasks, participants gained experience with actually using them and reported on their experience in the workshops and on the final project evaluation. The final evaluation asked participants to explicitly evaluate three types of peer learning activities:

1. informal or "get acquainted" in-class tasks (check marks in first two rows of Table 2),

2. tasks completed as a group in-class or in-lab with any grade constituting a small portion of a student's grade (four check marks in lower left corner of Table 2), and

3. out-of-class group programming projects with a combination of individual and group grades (check mark in lower right corner of Table 2).

The following sections report on their evaluation by participants, highlighting the advantages and disadvantages of each and providing specific examples of each type of activity. Respondents for the final project evaluation rated each type of

activity on a 1-5 scale relative to alternatives to using peer learning. A "1" indicates strong disadvantages for peer learning, a "3" indicates equal disadvantages and advantages and a "5" indicates strong advantages for peer learning. Table 3 summarizes these ratings.

4.1.1 Get Acquainted Tasks

Participants reported much experience with this type of activity. Sample activities for this type include simple introductions and discussions among group members to more elaborate team building exercises where each team must build a device to drop an egg 3 feet and have it stop within 3/4 of an inch from the ground (see [16] for details).

As shown in Table 3, all respondents have used this type of activity and felt it was generally advantageous. Respondents noted that students are more comfortable when they know each other and tend to achieve more as a consequence. The positive impact of active participation was noted by a number of people. A disadvantage is that the activities can take up too much class time.

Table 3: Cooperative Task Type Ratings

Task Type	Average Rating	Minimum Rating	Maximum Rating	Pct. Using Task Type
Get Acquainted	4.2	3	5	100%
Group Tasks in Class or Lab	4.5	3	5	85%
Out-of-Class Projects	4.2	2	5	69%

4.1.2 Group Tasks in Class or Lab

Examples of in-class and lab group tasks include:

- a group quiz where students work on an exercise as a group and turn in the results,

- a group teaching exercise where students are responsible for teaching a small topic to the other members of their group,
- a debugging exercise where students are paired to debug each other's code or a program given by the instructor, and
- a writing exercise where students work as a team to list important concepts learned that day or that week then write a short paper on how these concepts apply to their careers.

Some participants graded these activities as a group (with a relatively small weight in a student's overall grade) while others simply graded based on participation.

Table 3 shows the respondents were most enthusiastic about the advantages of this type of peer learning. Participants reported a great deal of success using this type of activity in the classroom. Participants felt these peer learning activities provide a needed change-of-pace to their classrooms and found students engaged and active with a topic as a result. In addition to making students more active participants in the learning process, these activities provide the instructor a chance to circulate in the room, learning about students in a non-evaluating context and engaging students in a small group setting.

The in-class activities have little risk of "failing" and are a good place to start for instructors considering the use of peer learning. In themselves, the activities do not cause dramatic change in student learning, but they can change the dynamics of a traditional lecture class and prolong student attention. They allow a student to answer as "we" rather than "I," which can increase a student's self-confidence to participate in discussions. These types of exercises are important for students to understand the value of collaborative learning in a setting that involves the instructor. Again, the only disadvantage noted by respondents is the loss of class time for covering other topics.

4.1.3 Out-of-Class Projects

A common out-of-class activity is to assign a large programming project in which each student group collectively designs and individually codes different aspects. Sample projects include:

- sorting, where each group member codes one sort algorithm and the group codes a driver program for testing,
- a maze search, where each group member codes a different maze search strategy with the group creating the core maze program, and
- a flight reservation system, which can accommodate a number of basic techniques such as linked lists, searching and sorting. In an object-oriented framework, each student can design and implement a different class for accessing flight and reservation data.

In contrast to relatively low-risk, in-class activities, these activities are a non-trivial portion of a student's grade and time devoted to a course and thus increase the risk of problems developing. These problems include: handling students' concerns that their grades are unfairly impacted by the performance of others, determining how to grade students in a group situation, preventing peers from unfairly "mooching" off of others' work and dealing with weaker or unmotivated students.

Fewer participants have used this type of peer learning because of many of these concerns, but as shown in Table 3, those who did use it were generally enthusiastic about its merits. There are many advantages that can make group projects a practical, useful and even natural approach to work in a course. Use of project teams can accommodate larger numbers of students with limited faculty resources. Group projects have a natural use in the introductory computer science curriculum where students begin to use data structures and do programming-in-the-large. For more realism students can work on assignments that are larger than a single student can accomplish alone. Finally, in spite of problems that can

occur, students working together develop a better understanding of the material than they could accomplish alone.

4.2 Logistics of Using Peer Learning

In addition to different types of activities, there are many other organizational details associated with using peer learning. These logistics were an important part of the workshops with the issues and results from the discussions given in the following sections.

4.2.1 Courses for Use

Project participants reported using peer learning in a range of introductory computer science courses from introductory programming to more advanced data structure and algorithm courses. Participants also used peer learning in literacy courses and integrated computer science/engineering courses. In-class activities occurred in all types of courses. Generally project participants who have successfully introduced large scale, out-of-class, programming-intensive group projects have done so in courses involving data structures and algorithms.

According to one participant's experience, long-term groups may not be appropriate in computer literacy courses. In this experience, some students worked on a set of self-paced exams while other students were grouped to coordinate activities on a set of exercises throughout the course. The participant found that the self-paced approach was more appropriate for this type of course.

4.2.2 Group Composition

There is much variation in size and selection of groups used for cooperative learning. In developing specific tasks, participants generally suggested group sizes of 3-5 with pairs of students when appropriate and larger groups for less formal activities. Groups that are too large do not function well on larger projects.

Depending on the activity, groups themselves can be created on an informal (ad hoc) basis or can be formally created for a longer term. Most frequently, in-class activities use informal groups while out-of-class projects group students for the duration of a project and sometimes for the entire course. Long-term group assignments allow students to get comfortable within their group, but do not allow as many interactions between different sets of students.

Actual selection of the group members can be done by the instructor or the students themselves. The general belief of project participants is that while student selection is fine for short-term informal groups, long-term formal groups should be selected by the instructor. The latter approach motivates students to meet and work with students other than their friends. It also reduces alienation for students without previous classmate connections.

One participant establishes the use of long-term "base" groups in the classroom to provide academic support in a suburban public university whose students are culturally diverse and primarily commuters—a setting that might not appear to be a good place for peer learning. Peer learning is stressed as an enhancement to the typical lecture with many activities throughout the course. Group activities are graded, but account for a modest 15% of the total grade. Because the groups stay together during the entire course, their primary purpose in not evaluation, but to serve as a peer support structure within the course.

4.2.3 Group Dynamics

One of the issues with large-scale, group exercises is the dynamics of how students work together. Participants note that a teacher cannot simply tell students to "work in groups." Students must be taught to work cooperatively in teams and should understand how team members and team projects will be evaluated. Group projects should be initiated with team-building activities (see Section 4.1.1). Explicit roles can be assigned to team members (e.g. leader, reader, recorder) to en-

courage involvement by all members and discourage dominance by one person. One participant explicitly incorporates peer learning assistants into the group learning process [17]. These upper-level undergraduate students are associated with project groups and are trained to help facilitate group dynamics.

4.2.4 Grading

Grading cooperative exercises and projects has been the subject of much discussion. Should each student be graded individually or should all members of a group receive the same grade? Participants generally agreed that grading can be a difficult aspect of using peer learning.

Group activities that make little contribution to a student's overall grade create few problems, while group projects with a larger contribution can create problems of evaluation. One solution used by participants is to reduce the contribution of grades for group work in calculating individual student grades. This approach lessens the impact of group grades, but may mean the contribution of group grades does not correspond to the amount of effort required of students for the work. The justification is that this evaluation approach lessens group problems and that the group work can be viewed as a catalyst for learning the material with other means such as examinations for actually evaluating the understanding.

When a group project grade is significant to a student's course grade, then students need to believe that they are being fairly graded for their individual contributions or they may not be open to the use of cooperative learning. The typical approach used by participants is to first grade and assign a group grade for the project as a whole. In addition, each group member turns in an individual assessment of all members with weights for individual contributions to the group. These weights, along with student comments, are used by the instructor to create scaling factors, which are multiplied by the group grade to yield individual grades. This process of self-evaluation is also important in helping a group understand how

to function better in the future. It promotes *individual accountability* on the part of each group member, a basic element of a good cooperative task [6].

4.2.5 Appropriate Tasks

Participants in the workshops discovered that there is not a standard use of peer learning. Rather, as shown in Table 2, there are different types of activities that serve different purposes and are appropriate for different situations.

It is important that an instructor use a peer learning activity that is a good fit for the learning objective and one in which it is both natural and beneficial for the students to work together. If students cannot see a benefit to working as a team, they may prefer to work individually rather than as part of a team—a good cooperative task needs to have *positive interdependence* between group members [6].

Evaluating the appropriateness of peer learning and convincing students of the benefits of working in groups create additional work for the instructor. In-class activities not only require the instructor to restructure lecture time, but also to develop peer learning exercises that can be utilized during each class. Careful planning regarding individual roles within the group is necessary for successful closed-lab group activities. Larger, out-of-class projects place even more importance on a the appropriateness of a given task for a group and the process of group dynamics.

4.2.6 Amount of Peer Learning

Our experiences indicate that peer learning should not be the only type of activity that students participate in and are evaluated on in a course. Workshop participants used a variety of peer learning techniques, but in all cases there was a significant portion of student work individually performed and evaluated.

In the final project evaluation, participants were asked about the maximum

percentage that group work should contribute to a student's overall course grade. Respondents indicated a range of 5-45% with a median of 20%. These results indicate that participants believe the use of peer learning is important, but it is just one aspect of the overall approach needed in the instruction of a course.

4.3 Additional Issues/Considerations

Additional issues and concerns related to peer learning have been raised by participants over the course of the project. Some of these are side effects of the use of peer learning while others are lingering concerns. The following sections list the outcomes on these issues.

4.3.1 Coverage of Material

A problem often associated with introducing group work in the classroom is that it reduces time available to "cover" material through lecture (see [14] for an excellent discussion of this and related problems). Our experience was inconclusive on this issue—some participants reported that they were actually able to cover more material while others covered less.

However, there was a strong feeling amongst participants that student learning should take precedence over coverage. Thus it makes no difference how much material is covered; it is only important that a student learns and understands. Peer learning activities allow students to be actively engaged in learning a topic which helps with overall understanding.

4.3.2 Breaking Barriers

Many participants reported observing new working relationships and friendships across cultures and groups that might not have occurred without peer learning. Another participant observed that out-of-class group projects required students to break the effects of "wired" dorms where students prefer to work in their rooms.

The group projects forced students to socialize with their peers.

4.3.3 Gender

The project participants did discuss grouping students based on gender with a general belief that group projects can help to attract and retain female students to the discipline. In assigning students to groups, some participants tried to mix genders within each group while others tried not to assign only one woman to a group. However, no specific results are available on what gender-based groupings work best.

It is interesting to note from Table 1 that 50% of the workshop participants were women. This relatively high participation level indicates that peer learning is a pedagogical technique of interest to women faculty members.

4.3.4 Individual versus Group Work

Some participants noted a negative side-effect of introducing peer learning into a course—the line between individual and group work becomes blurred. As observed by one participant, the enforcement of the "work alone on out-of-class programming projects" edict is much harder to enforce when students work in teams in class. The students have difficulty separating out the "now is the time where I have to demonstrate I can do this on my own" that is normally associated with outside projects. As a consequence this instructor has lowered the significance of out-of-class, individual projects as students work together on them in the same way they work together on in-class, group assignments. This same blurring effect has an impact across courses as well.

5 Assessment of Peer Learning

In addition to task development and the logistics of fostering peer learning, the project participants shared and discussed different approaches to both the assess-

ment of peer learning as a pedagogical technique and the assessment of cooperative work done by students. They were also involved in the assessment of the workshops and the project itself. Section 4.2.4 presented approaches for the assessment of student work; the following sections present approaches on assessing the effectiveness of peer learning as a technique in the student learning process.

5.1 Assessment as a Pedagogical Technique

All pedagogical techniques should be assessed in order to determine their merits in a given environment. This assessment includes formative assessment during a course, summative assessment of a course, and assessment of the long-term effects of the teaching technique.

5.1.1 Formative Assessment

Formative assessment can take several forms. Faculty observation of students participating in in-class group exercises is one way of obtaining immediate feedback on the success of the peer learning technique. By circulating through the class, teachers can observe how students are interacting.

Another immediate assessment technique is the use of end-of-class evaluations. Also called "two-minute papers," these evaluations allow students to provide written feedback on the success of a specific class. For these papers, the teacher directs student feedback by asking them to respond to particular questions regarding a peer learning activity or the class in general.

The advantage of both of these formative assessment techniques is that they can be carried out during the course and take up little class or instructor time. They also provide the teacher with information that can be immediately used for organizing future in-class activities. Participants typically use faculty observations and informal assessment as the first tools for measuring the effectiveness of the use of peer learning.

5.1.2 Summative Assessment

Summative assessment takes a longer term, often more formal, approach to measuring the impact of peer learning as a pedagogical technique. One relatively straightforward approach available at institutions that use standard school course evaluations is to compare evaluation results for control and experimental sections of a course. The problem with this approach is the difficulty of separating out the effects of peer learning from other aspects of a course; these standard course evaluations are often general and do not focus on the technique in question.

Pre and post surveys can be used as an alternate summative assessment approach to focus more specifically on the effect of peer learning activities. These surveys can be a mix of quantitative and qualitative questions. By comparing student opinion before and after the course, results can be obtained about the effectiveness of the peer learning activities.

On a strictly quantitative basis, student grade and retention results can be compared with prior offerings of a course to see if the peer learning activities have resulted in measurable differences. Again, problems can occur in separating out the effects of peer learning from other differences in the respective courses.

All of these summative assessment approaches have been used by some participants in the project. More participants are moving beyond using only formative assessment approaches and incorporating these summative approaches in their assessment.

5.1.3 Long-Term Effects of Peer Learning

Measuring the long-term effect of peer learning continues summative assessment work to examine the impact of a change over multiple years. There are a number of hypothesized effects to be measured. These effects include:

- Better retention of students will result because students have more opportunities to make contacts with their peers. Students will be less likely to feel

isolated and drop the course or major as a result.

- Student performance in the course with peer learning and in courses later in the curriculum will improve due to creating an environment with more active learning.

- Students will be better prepared for the work environment beyond graduation and therefore be more successful in their jobs due to the peer learning experiences.

Most participants have not formally evaluated the long-term effects of using peer learning. These effects will be examined as part of ongoing assessment efforts.

5.2 Assessment of the Project

In order to assess the success of this project, participants were asked to complete a survey following each workshop and at the end of the 1996-97 academic year. The survey results indicate that all participants consider this project to be beneficial. Participants indicated that the workshops gave them new ideas and the confidence needed to incorporate these techniques. In terms of the impact of peer learning on student attitudes and learning in the affected courses, a majority of respondents indicated that students were more satisfied with the courses when peer learning techniques were used. The remaining respondents indicated that they could not measure or observe a discernible effect on student learning.

6 Lessons Learned

The project has served to bring together a diversity of educators from a variety of institutions, both experienced and previously inexperienced with the use of peer learning. Through the course of the project, the participants have learned a number

of lessons to be conveyed to the larger computer science education community. These lessons are summarized in the following:

- *Peer learning is important.* It has a place in teaching the introductory computer science curriculum, but should not be used as the only technique.

- *Start small.* Peer learning can range from informal, small group exercises in class to more formal, group projects done outside of class. The best way to gain experience with peer learning is to begin with some relatively "low-risk" activities in class and then consider larger, out-of-class projects as appropriate.

- *Instructors must be willing to relinquish control.* The use of group exercises changes the dynamics in a classroom as students work on a problem without direct instructor involvement. This change from the traditional lecture often enlivens the classroom, but instructors and students need to grow comfortable with it [14].

- *Group project grading can cause anxiety for students.* Stronger students may see the group projects as a threat to their course grades. Group projects should be designed carefully to consider the needs of both weaker and stronger students. In evaluation, each student should get a grade that is based both on the group effort and each student's individual effort.

- *Group projects require careful planning by the instructor.* The planning is often more important than individual projects as the instructor must consider the role of each group member.

- *Students need to see the benefit for group activities to work.* Group tasks should be a welcome change of pace and selected tasks should clearly necessitate or benefit from group solution.

7 Summary

In summary, the project has illustrated that there is a wide variety of peer learning activities that can and are being used. The results show that the impact of this work on the respective campuses has been generally positive in terms of student response. More importantly, there is a strong feeling amongst participants that this is a good and useful technique that is appropriate for the introductory computer science curriculum. More information on the project, specific group activities developed and assessment mechanisms is available [16].

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