Structured Peer Learning Program – An Innovative Approach to Computer Science Education

Case Study

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ABSTRACT

Structured Peer Learning (SPL) is a form of peer-based supplemental instruction that focuses on mentoring, guidance, and development of technical, communication, and social skills in both the students receiving assistance and the students in teaching roles. This paper explores the methodology, efficacy, and reasoning behind the practical realization of a SPL program designed to increase student knowledge and success in undergraduate Computer Science courses. Students expressed an increased level of comfort when asking for help from student teachers versus traditional educational resources, historically showed an increased average grade in lower-level courses, and felt that the program positively impacted their desire to continue in or switch to a Computer major. Additionally, results indicated that advances in programming, analytical thinking, and abstract analysis skills were evident in not only the students but also the student teachers, suggesting a strong bidirectional flow of knowledge.

Keywords

cooperative learning; structured peer learning; bidirectional learning; computer science; undergraduate education; active learning

1. INTRODUCTION

Compared to Biology, Chemistry, or Physics, the discipline of Computer Science is relatively new, having emerged into the public consciousness as late as the mid-1900s, see [3]. However, the Computer Science job market is consistently strong, and Computer Systems Analyst and Software Developer jobs have been ranked at the top of the list of “The 100 best jobs” by the US News & World Report, see [6]. Unfortunately, due to the specific educational demands of the subject, this job market success does not automatically translate into success for students studying Computer Science and Engineering. Computer Science requires a unique mode of thought, emphasizing critical thinking, extensive analysis, and a degree of creativity, and also requires from students the ability to express themselves using the very strict syntax of code. Much like writing in English or a foreign language, students must learn the intricacies of using a programming language, and as many as 40% of students entering the Computer Science major have never seen a line of code before, see [11].

These challenges can be difficult for Computer Science educators to overcome. Not only must students be taught a plethora of abstract concepts, but they require the experience and knowledge necessary to concretely implement them. To this end, instructors have employed a number of traditional methods in an attempt to establish and then reinforce concepts in the minds of their students. These methods often focus on one-directional learning (lecture) and the issuance of reinforcing assignments (homework), and while these approaches are linchpins in any successful learning experience, some of their more outstanding drawbacks have been shown to have an especially deleterious impact on students of Computer Science. Lectures and homework have a tendency to place students in passive roles, to emphasize one-way communication, and to require a large amount of unguided time outside of class. This can lead to students improperly reinforcing what they have learned which can lead to the repetition of mistakes and misconceptions. Furthermore, these methods can be distinctly unsuited to teaching complex abstract material, see [1].

These weaknesses in traditional methods have led to the creation of several supplementary means of instruction intended to engage students in a more active way, see [4, 5, 12]. Including the concept of SPL. SPL is similar to Peer Tutoring, which is a form of supplementary instruction in which people from similar social groupings, who are not professional teachers, help each other to learn and learn themselves by teaching, see [4, 5, 12]. SPL differs from Peer Tutoring in that the system is formalized (with students being hired by and working directly for the department), and in SPL emphasis is on bidirectional learning and development of not only the students who are receiving aid, but of the student teachers as well. This system is capable of addressing many of the weak points in traditional learning, acting as a supplement to more passive methods. By providing a resource to students comprised of their peers, students are more able to engage with the material they are learning, and are more comfortable while doing so, see [6]. Students are encouraged to participate actively, communication becomes bidirectional, and mistakes can be corrected before they become reinforced. Finally, SPL offers students a relaxed learning environment in which they can ask questions without feeling the pressure of authority, increasing the number of students seeking assistance as well as improving the learning experience of those who do.
2. STRUCTURED PEER LEARNING

The Computer Science and Engineering (CSE) department at Texas A&M University established its structured peer learning (SPL) program with the goal of increasing retention in CSE, with the additional, related objective of increasing student success in Computer Science courses. The program is staffed by high-performing students who are hired part-time and assigned specific Computer Science classes that correlate to their proficiencies (generally based on prior outstanding performance in the courses they are assigned to teach). As these students graduate and leave the program, they are replaced with new high-performing students, generally selected from the lower-level undergraduate body. In this way, new student teachers are constantly cycled through and afforded the chance to learn from the opportunities provided by the program, and the relevancy of student teacher classroom experience is kept current by ensuring that student teachers assigned to a specific class have recently taken that class.

Student teachers are compensated by the department, are required to complete an initial training regimen, and are required to attend training sessions every semester for purposes of professionalization. All student teachers must abide by a code of conduct and a set of rules established by the university and the CSE department, and are expected to represent the school in a dignified, professional manner.

2.1 Benefits to Students

There are several ways in which student teachers provide assistance to students:

- Assisting, tutoring, and instructing directly in Computer Science course labs. This allows students to address issues which are fresh in the minds of students, and to provide direct assistance as students are working on completing assignments.
- Providing dedicated hours during which students can approach student teachers for one-on-one tutoring. Student teachers also enroll in any electronic resources (message boards or forums) tied to the class, and regularly respond to questions posed by students on these media.
- Leading supplemental classroom-based instruction for groups of students. These sessions are generally designed to review concepts presented in lecture, and are oriented towards reiterating points so that students strengthen their grasp on course material.
- Formal classroom direction is not disseminated through student teachers. Students do not receive assignments from student teachers, and student teachers are not able to instruct students to perform course objectives. This is very important in maintaining a peer relationship between student teachers and students.

We believe that this space between student teacher and formal instructor is a necessary condition for the unique dynamic that develops between students and their student teachers. Instead of being formally empowered with authority in the course or passing down mandates from “on high”, student teachers are able to act as relatable resources for their students, and are able to provide insight not only into technical matters, but also into the social, cognitive, and circumstantial factors surrounding an undergraduate career that includes a Computer Science curriculum.

2.2 Benefits to Student Teachers

A critical component of SPL, and one that differentiates it from Peer Tutoring, is the vast number of benefits enjoyed by student teachers both while they remain part of the program, and after they have graduated and moved into further education or the workforce. Many of these benefits are academic:

- Student teachers are required to repeatedly teach complex Computer Science topics to students, which serves to cement an understanding of those concepts in the student teachers’ minds. While student teachers are generally already high-performing students, this repetition helps to promote further mastery of many topics that are central to their success in the field.
- Computer Science is a field in which many problems can be solved in multiple ways, and as such student teachers are often exposed to alternate solutions when assisting students with assignments. This encourages a flexible mode of thought and a broad range of thinking, which helps to expand the skill set of student teachers.
- Because different professors may teach the same course differently and student teachers generally assist any and all students in a particular course, regardless of professor, student teachers are exposed to multiple facets of the subjects they teach, which broadens their perspectives and allows for a more complete education on the topic.

In addition to these academic benefits, student teachers are exposed to many advantageous scenarios which may increase their success in the workforce and/or graduate school:

- In the implementation of SPL in the CSE department at Texas A&M University, student teachers assist in running the SPL program, and undertake many projects which provide support, directly or indirectly, to the department. These projects range from managing scheduling and assisting with hiring, to website maintenance and construction, to the development of applications and interfaces that facilitate the success of other student teachers. These projects and responsibilities cultivate valuable skills and experience in the student teaching staff, and can also help to strengthen student teacher resumes.
• By interacting in a work environment with one another, student teachers build a network of high-performing peers that may carry forward into their future careers.

• Student teachers are well-positioned to mentor not only their students, but each other as well. Valuable experience gained during internships, co-ops, or employment, as well as impressions from courses taken, can be shared by more senior student teachers with their juniors.

These benefits can greatly impact student teachers, and serve to provide distinct benefits to the active student body that may not be seen in other methods of education, such as traditional Peer Tutoring, see [2].

3. HISTORICAL DATA

The Computer Science and Engineering (CSE) department at Texas A&M University performed research in 2007-2008 on the effectiveness of the SPL program as it pertains to student academic success, the results of which were submitted to the Texas Higher Education Coordinating Board but not formally published. Students were surveyed to determine whether they asked questions of student teachers during the semester, and their GPAs (grade point averages) were assessed at the end of their courses. The results indicated significant improvement in the academic performance of underclassmen who took advantage of the SPL program, with less conclusive results for students in upper level (junior and senior level) courses.

3.1 Methodology

Approximately 1100 students taking Computer Science courses were surveyed as part of the study, with about 500 responding (approx. 200 of whom were in freshman level courses, approx. 100 in sophomore level, and approx. 200 junior and senior level). Information was sought from students whether or not they asked Student Teachers any questions throughout the semester. Those students course grades at the end of the semester were recorded. Grades were then converted to a 4-point scale and averaged by course level.

3.2 Results

Students in Freshman and Sophomore level classes showed a clear increase in grade earned (Fig. 1), with students in freshman classes who asked questions of Student Teachers during the semester earning an average grade of 2.77, while those who did not ask questions of Student Teachers earning an average grade of 2.09, a difference of 0.68 points. Students in sophomore level courses were also greatly benefited, with students who asked questions earning an average grade of 2.95 and students who did not earning a grade of 2.36, a difference of 0.59 points. The benefits to students in junior and senior level courses were less clear (2.96 questions, 2.95 no questions). Furthermore, 65.48% of the students who asked questions ended up “succeeding” (defined as earning either an A or a B grade) in their courses, whereas only 58.34% of students who did not ask questions ended up succeeding (Fig. 2).

Finally, students were surveyed at the end of semester to evaluate their level of comfort in asking questions of instructors, teaching assistants (TAs) and student teachers (Fig. 3). In freshman classes, a greater proportion of students indicated that they were comfortable asking questions of student teachers (87%) than indicated that they were comfortable asking questions of TAs (83%) or instructors (74%). Similarly, more sophomore students felt comfortable asking questions of student teachers (91%) than did those who felt comfortable asking questions of TAs (89%) or instructors (62%). In upper level courses, students were most comfortable asking questions of instructors (92%), followed by student teachers (88%) and TAs (68%).

4. RESEARCH OBJECTIVES

The SPL program in the CSE department at Texas A&M University was established as a means to increase retention in-major, but it has also proven an excellent testbed for evaluating the potential benefits of SPL itself. The program was not designed as a rigorous experiment, and no controls were implemented as part of this program, as the initial and
When I do not understand a topic, student teachers in general were mostly positive. A total of 62.1% of respondents asserted that the experience increased their comfort in asking questions of student teachers, teaching assistants (TAs), and course instructors by evaluating the statement “I am comfortable asking ___ when I do not understand a topic being discussed in class.” Responses were rated on a 4-point scale (4—strongly agree, 3—agree, 2—disagree, 1—strongly disagree). Students rated their comfortability level with student teachers (Fig. 4) at an average of 3.63 (standard deviation 0.54), displaying a consistently higher level of comfortability than with TAs (3.36, standard deviation 0.69) or instructors (3.32, standard deviation 0.69). Additionally, students were much more likely to rate their level of comfort with student teachers at the maximum possible score, with 70.8% of responses falling under “strongly agree”, compared with 52.4% and 48.4% for TAs and instructors, respectively.

Impact of student teachers on CSE retention was mostly positive. Students were asked whether student teachers had a positive impact, negative impact, or no impact on their intentions to continue in, or switch to, a CSE major. In total, 70.7% of responses indicated that they were swayed towards a CSE major by student teachers, with 28.6% professing no impact on their educational goals, and only 0.7% claiming a negative impact.

Former and graduating student teachers were asked to evaluate the ways in which the SPL program affected their technical skills, and 100% of respondents indicated that their coding and programming concept skills were improved by participation in the program. Respondents also overwhelmingly indicated that their interview skills were improved significantly by serving as a student teacher, with 93.1% of respondents asserting that the experience increased their confidence in answering technical questions.

Free responses from the former and graduating student teachers were mostly positive. A total of 62.1% of respondents included praise for the fact that as student teachers they were able to learn many important computer science related social skills while they taught others. Additionally, the vast majority of respondents expressed satisfaction with the program, with 96.6% of responses indicating an overall positive experience.

### 5. METHODOLOGY

We collected data primarily through means of online and written surveys. At the end of each Computer Science course in which student teachers played an instructive role, students of the course were asked to complete a short questionnaire evaluating the student teachers they interacted with. Additionally, former and graduating student teachers were contacted and asked to complete a survey evaluating the efficacy and impact of the SPL program on their college and/or professional careers.

Student survey data was collected beginning in spring of 2009 and continued through spring 2016. During this time we received and analyzed a total of 4709 responses. Questions encompassed student level of comfort in asking questions of student teachers vs traditional instructors, impact of SPL on student understanding and course grades, impact of student teachers on CSE retention, and effectiveness of the student teachers in general.

Former student teacher survey data was collected in spring of 2016. We received 33 responses from students who worked as student teachers at some point during the period from 2007 to 2016. Questions encompassed overall satisfaction with the SPL program, personal benefits attained from participation in the program, and the professional and academic impact of serving as a student teacher. Many of the questions asked were descriptive multiple choice, but respondents were also encouraged to provide comments and suggestions for the program in free response form.

### 6. RESULTS

Students were asked to rate their level of comfort with asking questions of student teachers, teaching assistants (TAs), and course instructors by evaluating the statement “I am comfortable asking ___ when I do not understand a topic being discussed in class.” Responses were rated on a 4-point scale (4—strongly agree, 3—agree, 2—disagree, 1—strongly disagree). Students rated their comfortability level with student teachers (Fig. 4) at an average of 3.63 (standard deviation 0.54), displaying a consistently higher level of comfortability than with TAs (3.36, standard deviation 0.69) or instructors (3.32, standard deviation 0.69). Additionally, students were much more likely to rate their level of comfort with student teachers at the maximum possible score, with 70.8% of responses falling under “strongly agree”, compared with 52.4% and 48.4% for TAs and instructors, respectively.

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7. DISCUSSION

Computer Science education presents many unique challenges, and creating an environment in which students are willing, capable, and interested in learning can be a very difficult task, see [7]. The SPL program has shown that it is successful in creating an environment in which students are comfortable seeking help, and that the assistance provided by the student teachers has, in the students’ estimation, greatly increased students ability to succeed in Computer Science courses. Additionally, results show that, in the majority of cases, the program inclines students towards staying in, or switching to, a CSE major.

In addition to the improvements experienced by students who received help from the SPL program, benefits appear to have been reaped by the high-performing students serving as student teachers. Improved interview and communication skills were indicated by an overwhelming majority of former student teachers, and an improvement in programming and abstract thinking skills were enjoyed ubiquitously. This data supports the hypothesis that SPL is a program that emphasizes bi-directional learning, in which both the student and student teacher are able to benefit from the process of teaching. Student teachers also expressed general satisfaction with the program. Many respondents indicated that they felt they had succeeded in providing effective mentorship to students, in areas directly related to programming as well as in other related skills.

The historical data from 2007–2008 regarding student comfort in asking for help from student teachers agrees with the more recent data. In addition, the data concerning GPA provides concrete evidence for our contention that student grades are impacted positively by the SPL program. This data establishes a clear increase in GPA for students in lower level courses who took advantage of the program, and shows that the SPL program is capable of meeting one of its primary goals which is increasing student success in CSE courses.

8. CONCLUSION

The SPL program in the CSE department at Texas A&M University has been successfully providing deep learning benefits to all participants for nearly a decade, and we believe that it not only provides an additional source of help to students who have needed it, but also motivates and inspires students to learn, creates an effective learning culture, and builds stronger social interaction and cognitive development. The program continues to develop based on the feedback we receive from both students and student teachers. It has increased in size since 2009, and continues to grow as it facilitates success in the undergraduate CSE bodies. The program is not perfect, and cannot ensure the success of every student, because those who do not wish to put forth the effort and seek help see no benefits from the program. However, we are confident that the methods used are effective and that the implementation of Structured Peer Learning at the department is on the right path.

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9. REFERENCES

[1] Bonwell, C. C. Enhancing the lecture: Revitalizing the traditional format. *New Directions for Teaching and Learning* 67 (1996), 31–44.

[2] Chen, C., and Liu, C. C. A case study of peer tutoring program in higher education. *Research in Higher Education* 11 (2011), 1–10.

[3] Denning, P. J. Computer Science: The discipline. *Encyclopedia of Computer Science*, 2000. Archived from the original (PDF) on 2006-05-25.

[4] Falchikov, N. *Learning Together: Peer Tutoring in Higher Education*. RoutledgeFalmer, New York, NY, 2001.

[5] Goldschmid, B. Peer teaching in higher education: A review. *Higher Education* 5 (1976), 9–33.

[6] Lazowska, E., Roberts, E., and Kurose, J. Tsunami or sea change? Responding to the explosion of student interest in Computer Science. Slides for CRA Conference at Snowbird, July 2014. Also Slides for NCWIT 10th Anniversary Summit in May 2014.

[7] Mhashi, M. M., and Alakeel, A. Difficulties facing students in learning computer programming skills at Tabuk University. *Recent Advances in Modern Educational Technologies* (2013), 15–24.

[8] Newcomb, T. M., and Wilson, E. K., Eds. *College peer groups: problems and prospects for research* (1966), Aldine Publishing Company.

[9] Prince, M. Does active learning work? A review of the research. *Journal of Engineering Education* 93, 3 (2004), 223–231.

[10] Ramaswamy, S., Harris, I., and Tschirner, U. Student peer teaching: An innovative approach to instruction in science and engineering education. *Journal of Science Education and Technology* 10, 2 (2001), 165–171.

[11] Stroustrup, B. Programming in an undergraduate CS curriculum. In *Proceedings of the 14th Western Canadian Conference on Computing Education* (New York, NY, 2009), R. Brouwer, D. Cukierman, and G. Tsiknis, Eds., ACM, pp. 82–89.

[12] Topping, K. J. The effectiveness of peer tutoring in further and higher education: A typology and review of the literature. *Higher Education* 32 (1996), 321–345.