AC 2009-2543: IN-CLASS PEER TUTORING: A COST-EFFECTIVE MODEL FOR ENGINEERING INSTRUCTION

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Abstract

The in-class experience in engineering education has not changed significantly in the last 100 years, although some instructors are attempting to replace didactic teaching with active learning techniques. Despite its promise, the impact of active learning can be limited due to the lack of social learning resources, such as individuals who can answer questions during active learning exercises. Peer tutors can provide this missing resource. A wealth of theoretical and empirical evidence demonstrates that peer tutoring positively impacts learning, self-confidence, and interest in the discipline. In-class peer tutoring (ICPT) addresses the limitations of active learning and utilizes an effective and accessible resource—the students. In ICPT, undergraduate engineering students with relevant experience act as teaching assistants for small groups of students during in-class active learning exercises. In the fall of 2007, Washington State University (WSU) researchers implemented an ICPT program in statics and mechanics of materials. Extensive data from surveys, focus groups, and interviews indicates that the program is valued highly by students and improves learning and self-efficacy. For example, more than 80% of students in these ICPT classes agreed with the statement "I wish my other courses used peer tutors." Tutors appear to be motivated by the benefits of helping other students without financial reimbursement. WSU's ongoing ICPT program can act as a model for other universities, demonstrating the potential of peer tutoring to transform engineering education.

Introduction

The quality of the classroom experience for engineering undergraduates has the potential to impact both retention of engineering students and student preparation for the workforce. Students who leave engineering often cite poor teaching as one of the primary reasons for their decision [1]. Progress has been made in identifying best instructional practices, such as active learning [2] and peer instruction [3-5], which have been shown to improve student learning and attitudes towards learning and retention [3-5]. Active learning techniques include brief in-class exercises in which students work alone or in groups to process concepts more fully than simply taking notes. An integral part of these exercises is the formative assessment process, where students receive feedback through purposive social interactions from other well-prepared students and/or the instructor. Due to large class size in most undergraduate engineering mechanics courses, which often include hundreds of students, instructor feedback is limited. In-class peer tutoring (ICPT) addresses this need and helps fulfill the promise of active learning for engineering education. ICPT programs use undergraduate engineering students with relevant experience as teaching assistants for small groups of students working on active learning exercises. ICPT programs build on best practices in educational research and leverage the directly available and affordable resource of undergraduate students.

What is Tutoring and Why is it a Good Idea?

A tutor is loosely defined as a person charged with the instruction and guidance of another, and tutoring takes many forms in grades K-16. At the university level, tutoring may occur formally in class, or informally out of class, such as in study groups or student lounges. Peer tutors may possess equal or more experience than target students, and support and training programs vary widely. Peer tutoring programs have shown multiple positive outcomes for both students and tutors in terms of learning, retention, and attitudes about the discipline, and other areas. The program described herein incorporates experienced peer tutors, and includes an in-class and out-of-class component, as well as a diverse set of support and training structures. Based on existing research, this combination has a high likelihood of positively influencing several essential student outcomes.

A wealth of theoretical and empirical evidence suggests that tutoring is tremendously valuable. Relevant theoretical constructs include a social constructivist view of learning [1], formative assessment, and Vygotsky's zone of proximal development [2].

Constructivist learning theories suggest that individuals learn and make sense of new materials and ideas within existing mental frameworks. These frameworks are complex interwoven sets of ideas and beliefs based on previous experiences. In order for learning to be effective, instruction must take into account these existing frameworks. Although some curricular developments, such as cooperative learning and personalized electronic homework systems, attempt to address these individual differences, they have not been broadly implemented. Most importantly, they are inherently inflexible because the learner cannot respond and interact with the instructor in a personalized way. Tutors, however, can listen and respond to individual ideas and beliefs much more than existing systems can.

Formative assessment, or continuous feedback provided to students in the absence of associated decision making (evaluation), has consistently been proven essential for student learning. The National Academy of Engineering named "Personalized Student Learning" as one of the greatest challenges for the next century, highlighting the importance of formative assessment. Formalized assessment systems used currently in higher education include questioning and office hours, which are an attempt to embrace open dialogue. However, active learning exercises during regular class time are rarely given, and feedback from instructors and teaching assistances on assignments and exams is often sparse and general. Upperclassmen, or more experienced students, are an untapped resource that can address these shortcomings.

In his seminal work describing a sociocultural theory of learning, Vygotsky described the zone of proximal development [2]. The essence of this concept is the distance between the actual developmental level, as determined by independent problem-solving, and the level of potential development, as determined by problem solving under adult guidance, or in collaboration with more capable peers. Vygotsky argues that students learn most effectively when they operate within this zone. In other words, students should spend time in the zone that is just outside of what they can do on their own, and this time should be supported by those who can help students achieve a greater level of understanding. It is also important that the individuals helping students represent differing levels on the expert-novice spectrum [3]. Vygotsky posits that the mental

models of "near peers," or those who have just learned certain material, are different than the mental models of experts in the subject, and that therefore, they use different language to discuss what they have learned. Therefore, one reason peer that tutoring works may be that tutors and tutees speak a similar language, whereas teachers and students do not. During peer tutoring, the tutee plays a more active role than in the teacher/student relationship. The student who is tutored by a peer feels freer to express opinions, ask questions, and risk untested solutions with a peer tutor, because both individuals are closer in terms of prior knowledge and status. This is why conversations between peer tutors and their tutees are high in mutuality even though the individuals are not completely equal in status. These interactions are likely to occur in the zone of proximal development.

There is also substantial empirical evidence on the benefits of tutoring. Previous research indicates that improved learning (as measured by classroom exams and national standardized exams) [4], attitudes about the subject matter [4], attitudes about school [5], self-concept [5], and retention [6] are all potential positive outcomes of peer tutoring programs. Even with a wealth of evidence on the value of peer tutoring, use of this valuable resource to assist less experienced students in the learning process is rare in the undergraduate environment.

What is ICPT?

ICPT is defined as utilizing students who have recently taken a particular course (e.g. statics) to assist students on active learning exercises in this course during lecture. ICPT was implemented in statics and mechanics of materials (MOM) at Washington State University each semester from Fall, 2007 to Spring, 2009. The program is also currently being implemented in statics at Oregon State University. Currently, data is available for fall 2007 and spring 2008 at WSU only. Table 1 shows enrollment and peer tutoring numbers for each course. Tutors were selected by the instructor based on academic achievement and their interest in helping other students.

	Statics Fall 2007	MOM Fall 2007	Statics Spring 2008	MOM Spring 2008
Course Enrollment	60	39	58	55
Number of Peer Tutors	5	8	6	3

Table 1: Course Enrollments and Number of Peer Tutors in ICPT Courses

The original program consisted of weekly meetings with the instructor and other tutors and the in-class component. In the in-class component students who have taken statics (or mechanics of materials) in the previous year assist students during lecture with active learning exercises about once per week. The active learning activity lasted between 20 to 40 minutes during the 50-minute class period, and consisted of typical homework problems and ranking tasks, which were challenging enough so that most students could not complete them on their own. Ranking tasks were only used in the MOM sections. Ranking tasks are comparative exercises in which students are provided with six similar scenarios and asked to rank the scenarios based on a specific criteria. For example, students were given six identical simply-supported beams with the same distributed load. They were then asked to rank locations in the cross-section based on the bending moment, shear force, normal stress, or shear stress at these locations. Ranking tasks

were chosen because they were challenging enough that students needed to interact with each other and tutors to successfully complete the exercises.

The instructor provided exercises to tutors about one week prior to the ICPT session. One or two days prior to the ICPT session, the instructor discussed exercises with all peer tutors. In these meetings, the instructor provided insight into normal stumbling blocks for students during such exercises, and tutors asked for clarification on aspects of the problem that they did not understand. In the fall of 2007, the ratio of tutors to students was approximately 1:5. In following semesters, this ratio was change to approximately 1:10 based on student feedback. Although this ratio is the goal, ratios sometimes differed slightly based on availability of effective tutors. Tutors were compensated with gift certificates. In fall, 2007, amounts were $150, and this was reduced to $100 based on tutor feedback. The current reimbursement scheme and implications are discussed below.

Evaluation of WSU's ICPT Program

Since its inception in fall, 2007, WSU has assessed the ICPT program with a variety of methods. These methods included a survey with Likert scale and open-ended questions, focus groups with tutors, and individual interviews with students who experienced peer tutoring. The survey and focus groups are considered assessment, primarily because they are not guided by a specific theoretical framework and associated research questions. However, the individual student interviews are part of a newly initiated research program on the ICPT program funded by the National Science Foundation.

The survey included seven Likert-scale questions (listed in Table 2 below), age, gender, and ethnicity questions, and two open ended questions. The data for age, gender, and ethnicity have not yet been analyzed.

Likert-scale questions ranged from completely agree, somewhat agree, neutral, somewhat disagree, and completely disagree responses, with associated values of 5-1, respectively. Question 4 is a reverse question for reliability. A response of 1 to this question would indicate that the student strongly disagreed with this statement. Average responses for each question are listed in Table 2. Although averaging Likert scale responses is not considered reliable due to the potentially non-scalar quantity of the responses (i.e. the distance between 5 and 4 may not be the same as the distance between 4 and 3), average values are still helpful in the interpretation of the pool of responses. Results for Questions 1 and 3 show that students see the value of the peer tutors. More than 80% of students in all four courses either completely or somewhat agree with these two questions.

Responses to Questions 1 and 3 as well as 2 and 6 indicate that, although students think that tutors are helpful and wish they were used in other courses, it is not as clear to these students that they have learned more or their performance has improved as a result of the peer tutors. This discrepancy is an interesting area for future research.

Some typical open-ended responses to the question "In what ways did the peer tutors help you this term?" were, "They were able to explain things in terms I could understand," and "[They]

explained concepts to me." Results of this survey indicate that students perceive that peer tutors are valuable in the course and helpful in learning.

Survey Question	Statics Fall 2007	MOM Fall 2007	Statics Spring 2008	MOM Spring 2008	Average
1. The peer tutors have been helpful to me in this course.	4.0	4.6	4.2	4.3	4.3
2. I have learned more in this course because of the peer tutors.	3.5	3.9	3.7	3.8	3.7
3. I wish that my other engineering courses used peer tutors	4.0	4.5	4.2	4.2	4.2
4. The peer tutors did not add any value to this course	2.2	1.5	2.0	1.9	1.9
5. The peer tutors were able to answer my questions	4.0	4.4	4.3	4.2	4.2
6. My performance in this course was improved because of the peer tutors	3.6	3.9	3.4	3.8	3.7
7. The peer tutors want me to do well in this course.	4.6	4.4	4.5	4.1	4.4
8. The peer tutors have gone out of their way to help me	4.0	4.1	4.1	3.7	4.0

Table 2: Results of ICPT Survey

At the conclusion of the fall 2007 term a focus group was held with tutors to assess the program. The facilitator asked tutors about factors that motivated them to participate in the tutoring program and what level of reimbursement was appropriate. Although the tutors indicated that they participated in the ICPT program to improve their understanding of the material and their communication skills, as well as for self-fulfillment, they also agreed that some form of financial reimbursement was necessary. All tutors present agreed that $100 was a reasonable amount. Since that time we have offered tutors $100 for participation in the program, and many tutors do not end up accepting their gift certificate at the end of the experience. When asked why, students commonly respond that they received enough personal benefit that they didn't think financial reimbursement was necessary. This is a remarkable and very important pattern. The sustainability of this program is greatly enhanced if there is little or no cost.

Selection of tutors has become much easier than at the beginning of the program. One instructor who implemented the ICPT program has indicated that students often approach her requesting to be peer tutors. It appears that these students have a strong interest in helping other students and see the value in learning the material again through the tutoring process.

Conclusions

Substantial theoretical and empirical evidence from previous studies, as well as from the WSU assessment process, suggests that the ICPT program has a strong potential to have significant

benefit to students and tutors. It appears that students see tremendous value in the tutors and that tutors learn from their experience. More research is needed to investigate the efficacy of this program on important student outcomes. Two new research projects on the WSU ICPT have already begun, one focused on the impact of the program on student social capital, and the other on peer tutoring and students' self-efficacy in mechanics.

Social capital consists of the resources embedded in social networks that are accessed by members of that network. Initial results of the project on social capital indicate that students view the ICPT program as an essential and productive resource in the WSU engineering program. In today's financially distressed environment, utilization of affordable resources is particularly important. The knowledge that students bring into class from previous courses is a vital and largely untapped resource.

The impact of the ICPT program on students' MOM self-efficacy, or confidence in their ability to be successful in MOM, is also being investigated using in-depth interviews. Initial results indicate that students' interactions with peer tutors positively influence their MOM self-efficacy. It appears that students see these interactions as what Bandura calls mastery experiences [7], characterized by having more confidence after the interaction than before.

In order for higher education programs to be sustainable, several factors must be in place. The program must beneficial to students, be easily implementable by faculty, and be affordable. The emerging finding that students do not require financial reimbursement highlights the sustainability of the ICPT program. Results show that the program is valuable for students and tutors, and is easily implemented by faculty. The WSU ICPT program can act as a model for other engineering programs, and thus impact the culture of engineering education.

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