Do Active Learning Approaches in Recitation Sections Improve Student Performance? A Case Study from an Introductory Mechanics Course

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Abundant research leaves little question that pedagogical approaches involving active student engagement with the material, and opportunities for student-to-student discussions, lead to much better learning outcomes than traditional instructor-led, expository instructional formats, in physics[1-6] and in many other fields.[7] In introductory college physics classes, some departments have departed radically from conventional lecture-recitation-laboratory course structures, but many, including my own, retain the basic format of large-group classroom sessions (lectures) supplemented by smaller-group meetings focused on problem solving (recitations) and separate laboratory meetings. Active student engagement in the lectures is encouraged through approaches such as Peer Instruction[8,9] and Interactive Lecture Demonstrations,[10] and these approaches have been demonstrably successful.[1,2]

There has been far less research on the use of active-engagement pedagogy in recitation sections. In one recent study, student performance on two selected questions was compared for four different recitation styles, ranging from a pure instructor-led format to cooperative group problem solving with Socratic questioning from a trained teaching assistant.[11] The latter proved to be the most effective approach. These recitations, however, were held in conjunction with an alternative course structure based on the *Tutorials in Introductory Physics*[12] and included substantial TA training, so it is not clear how the results carry over to a more traditional course structure.

Informal observations suggest that at many institutions, recitations continue to be largely instructor led, with student participation consisting largely of posing questions to the instructor and offering suggestions toward the solutions of problems under discussion. For the most part that has been the case at my institution. This paper reports on a small-scale study of an effort to introduce active-engagement approaches in the recitation sections of an introductory physics class in which such pedagogical methods were already in use in the lectures. Compared to more traditional recitations, no significant difference in student outcomes was detected, and student satisfaction with the recitations decreased.

The class

The class was the first semester of calculus-based introductory physics at Tufts University, a highly selective private research-intensive university in the Boston metropolitan area. There were 161 students who finished the course, predominantly freshman engineering students. A large majority of the class had taken physics in high school, and most had taken calculus. The entire class had three 50-minute lectures plus one 50-minute recitation section per week. There was also a laboratory component, which was relatively traditional, was the same for all students, and will not be further discussed here.

The lecture portion of the class made heavy use of active-learning methods and was taught by an experienced instructor who had been using such methods for many years. Before class students were required to watch video pre-lectures and answer online conceptual questions,[13] and the class format was based on Peer Instruction,[8] with much of the class time devoted to conceptual questions (using electronic student response devices) and both small-group and all-class discussion. Interactive Lecture Demonstrations[10] were also used occasionally. Throughout the course considerable emphasis was placed on using and coordinating multiple ways of analyzing and representing physical situations,[14,15] similar to the "weakly directed approach" described by Kohl, Rosengrant and Finkelstein.[15]

There was weekly homework, with multi-step problems, context-rich problems that required the application of classroom physics in unfamiliar contexts, and questions that required multiple modes of reasoning and explanation (such as verbal and graphical as well as quantitative). No problems were assigned directly from the textbook, though some were adapted from textbook problems. Examination questions were similar in nature to homework, but were not directly derived from problems assigned as homework. Homework counted as 10% of the total course grade. The majority of the class (57%) reported spending five to 10 hours/week outside of class working on the course, much of it on the homework. (Fourteen percent reported spending less than five hours/week; the remaining 29% reported spending more than 10 hours/week.) Clearly the homework was experienced as challenging, but little time in lecture was spent specifically addressing problem-solving strategies. In particular, students were not given a specific rubric or algorithm to follow in solving problems. On both homework and exams, however, they were required to provide some account of their reasoning through words, diagrams, or other representations. Solutions

 DOI: 10.1119/1.5018689

consisting entirely of equations and computations, even if correct, could not receive full credit.

Recitations were used primarily to work on problem solving, by means of the assigned homework. There were seven sections, with enrollments ranging from 14 to 27, and an average enrollment of 23. Five of the sections were taught by an advanced doctoral student, and two by a tenure-track member of the physics faculty. Both had prior experience in teaching recitations, but neither had received any specific training on recitation instruction, although the faculty member had attended a workshop on physics pedagogy. Every student was required to enroll in a recitation section, but attendance was not mandatory, was not recorded, and varied from section to section and from week to week; typical attendance was in the vicinity of 60%. Students selected recitations based largely on scheduling convenience, and without information about the recitation instructor or instructional style, so it is reasonable to assume quasi-random distribution of students among the sections.

Each instructor chose some sections (two of five for the graduate student, and one of two for the faculty member) to teach in a traditional style: instructor-led, with students sitting individually, though with ample opportunity for students to ask questions and respond to questions and prompts from the instructor. The remainder (three of five taught by the graduate student, and one taught by the faculty member) were taught in a format informed by research into students' challenges in learning effective problem solving and active-learning approaches to addressing those problems.[1,16] There is considerable evidence that novice physics students frequently jump very quickly from the verbal description of the problem to equations[1,3,17-21] rather than constructing intermediate representations, such as pictures and diagrams.[17,19,21,22] Effective use of multiple representations has been associated with improved problem-solving performance,[15] although the connection is complex.[23,24] There is evidence that providing specific instruction in problem-solving techniques can be effective,[25,26] and that working in groups can be more effective than individual work,[27,28] provided that the group work is accompanied by other supports for the learning process.[29] The "whiteboard" format we used had the following principles:

- Students worked in groups of three to four, around whiteboards (2 ft × 2 ft, one whiteboard per group) and were asked to write only on the whiteboard.
- Each group was tasked with working on one of the homework problems.
- Students were asked not to begin with equations or numbers, but rather by representing the physical situation in one or more other ways, such as with a diagram or a graph.
- After each group had made some progress on its selected problem, the instructor would ask a group to present its analysis of the problem and facilitate a class discussion, guided by the recitation instructor.

Our hypothesis was that this more collaborative approach would engage more of the class in thinking deeply about the physics of the problems, focus their attention on the challenging task of understanding the physical situation under discussion, and increase their facility in using and moving among multiple representations. Within each section, the basic instructional format was held constant throughout the semester. Since each instructor taught sections in both formats, any differences in outcome could reasonably be attributed to the format rather than to the quality of the instructor.

There were a total of 71 students enrolled in the "Traditional" sections and 90 in the "Whiteboard" sections. Students did not know when they enrolled which format would be used, and it was not announced that different formats were in use, although no doubt many students became aware of the differences by word of mouth. Of course, not all enrolled students attended recitation, and it is possible that some students attended sections in which they were not formally enrolled. Despite these limitations, we have essentially randomly assigned populations of students whose course experience differed systematically only in the format of their recitation sections.

Results

The two populations were compared on three dimensions: overall course performance (a weighted average of exams, homework, labs, and participation); final exam grade; and student evaluations of the value of the recitation. Homework grades, which might seem to be most directly affected by the recitation, were not used because students had so many resources available for help on the homework that their homework grades were uniformly high.

Figure 1 compares the course performance measures of the two groups. On both overall course performance and final exam grade, the "Whiteboard" group scored slightly lower than the "Traditional" group, but the difference is not statistically significant ($p = 0.15$ for overall and 0.22 for the final exam). There is no evidence that the format of the recitations made any difference at all in the students' course or final exam performance.

Figure 2 compares the student responses to the question "Overall, how useful was the content of the recitation section in helping you understand physics?" collected via a voluntary, anonymous online survey. There were 51 responses (72%) from the "Traditional" group and 47 (52%) from the "Whiteboard" group. Responses were on a scale from 1 (very poor) to 5 (excellent). The averages for the two formats were 3.4 for the Traditional format and 2.9 for the Whiteboard format, a difference that is statistically significant ($p = 0.018$). Evidently the students preferred the traditional format. Open-response comments suggested frustration with the perceived inefficiency of the collaborative approach—too much time spent on incorrect ideas, too little guidance from the instructor, not enough time to get to all the problems.

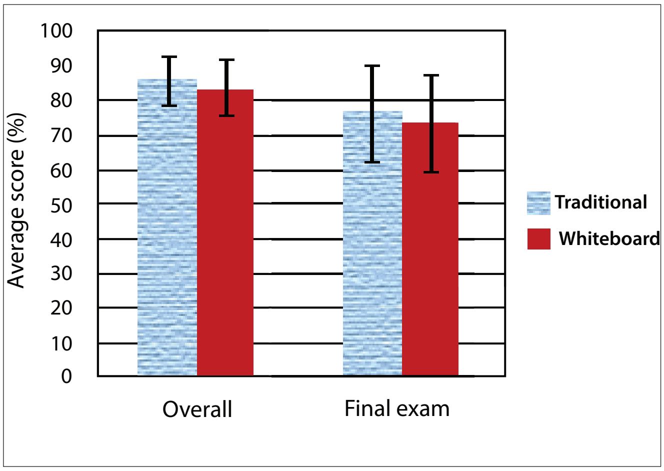

Fig. 1. Comparison of overall course score and final exam score for the students enrolled in recitation sections using the Traditional and Whiteboard formats. The error bars represent one standard deviation. The differences are not statistically significant.

Discussion

Clearly the shift in recitation format, as implemented, did not have a positive outcome that was discernible by the measures used. Student performance in the course and on the final exam was unchanged, and student satisfaction was lower. Methodological issues could be part of the explanation. As noted previously, a substantial number of students did not regularly attend recitation, and so could not be affected by the pedagogical approach. A much smaller but unknown number of students may have attended sections in which they were not enrolled, and might therefore have been counted in the wrong category. The measures being used, while unquestionably meaningful to students and customarily viewed as meaningful in academe, have not been systematically validated and certainly measure many attributes besides the problem-solving skills emphasized in recitation.

Still, there is abundant research indicating that problem solving is a significant obstacle to student success in introductory physics, and supporting the general pedagogical principles that the Whiteboard format was intended to incorporate, so it was perhaps not unreasonable to expect at least a small positive effect on student performance. It is therefore worth asking why no such effect was detected. Nothing in this study addresses that question, so what follows is speculative.

One possibility is that the recitation format was not sufficiently well designed, implemented, or supported to produce significant results. Heller and Hollabaugh, for example, emphasize that successful cooperative group work depends on careful attention to the size, composition, and management of the groups,[27] and Koenig, Endorf, and Braun point to the importance of TA training.[11] Some authors have shown success with highly explicit and consistent instruction in problem-solving strategy,[26,15] although in the case of the use of multiple representations, a weakly directed approach was found equally effective.[15] In a meta-analysis of studies across

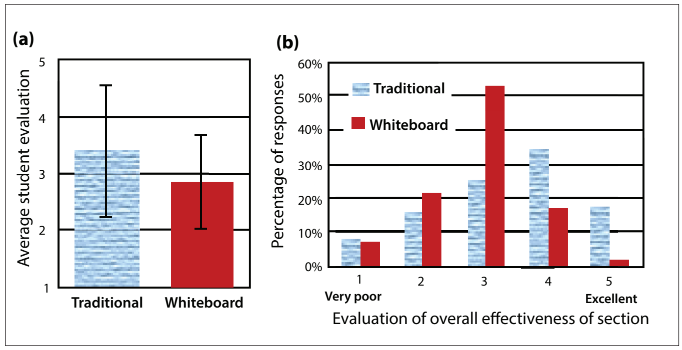

Fig. 2. Student responses to the question "Overall, how useful was the content of the recitation section in helping you understand physics?" for the students enrolled in sections using the Traditional (N = 51) and Whiteboard (N = 47) formats. (a) Comparison of the mean rating, on a scale from 1 (very poor) to 5 (excellent). The error bars represent one standard deviation. The difference is statistically significant (p = 0.018). (b) Histogram of student responses.

multiple science fields, Taconis, Ferguson-Hessler, and Boekkamp found that providing explicit guidelines and criteria, and immediate feedback, were crucial aspects of effective interventions, and that group work on its own, without those features, could actually be detrimental to performance.[29] The Whiteboard format as implemented may not have gone far enough in structuring the group work and providing the students with specific guidelines and prompt and consistent feedback, and greater training and supervision of the recitation instructors would no doubt have been valuable.

It is also possible that the performance measures used were too crude to pick up the changes in problem-solving approach fostered by the recitation intervention. We did not specifically evaluate students' problem-solving technique, except, as noted above, by requiring some explanation of their reasoning beyond the use of equations. In addition, exam problems often explicitly called for the use or interpretation of diagrams (e.g., free-body diagrams) or graphs, so students' spontaneous use of such representations would not necessarily have been apparent. On the other hand, to the extent that the goal is not to inculcate specific problem-solving strategies, but rather to make students more adept at solving problems, overall performance in solving the nontrivial problems posed is arguably a fair measure of performance.

A third possibility, however, is that recitations, however conducted, have only a weak influence on overall student performance in comparison to the many other aspects of the course: online pre-lectures and conceptual questions; lectures with active-learning components; challenging homework with varied and context-rich problems; laboratories; and access to help from faculty, TAs, and fellow students.

At a minimum, this study suggests that simply adding some active-learning approaches to recitation sections, without more extensive and integrated attention to problem-solving techniques, may have little effect on students' skills in introductory physics. And at least in this case, the effect on student satisfaction was negative.

Acknowledgments

I thank Prof. Cristian Staii and Jonathan Poage, the recitation instructors, for their cooperation and help in conducting this investigation.

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