A Preliminary Study of the Effectiveness of Different Recitation Teaching Methods

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Abstract. We present preliminary results from a comparative study of student understanding for students who attended recitation classes which used different teaching methods. Student volunteers from our introductory calculus-based physics course attended a special recitation class that was taught using one of four different teaching methods. A total of 272 students were divided into approximately equal groups for each method. Students in each class were taught the same topic, "Changes in energy and momentum," from *Tutorials in Introductory Physics* [1]. The different teaching methods varied in the amount of student and teacher engagement. Student understanding was evaluated through pretests and posttests given at the recitation class. Our results demonstrate the importance of the instructor's role in teaching recitation classes. The most effective teaching method was for students working in cooperative learning groups with the instructors questioning the groups using Socratic dialogue. These results provide guidance and evidence for the teaching methods which should be emphasized in training future teachers and faculty members.

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INTRODUCTION

Several years ago we decided to modify our large traditionally taught introductory calculus-based physics course for first year engineering students at the University of Cincinnati. This course had become a barrier for beginning engineering students who had difficulty understanding basic physics concepts and were unable to solve multi-step problems using these concepts. Since previous studies have shown that student understanding of concepts is improved by using instructional methods that incorporate active engagement instruction [2] and research-based inquiry activities [3], we aimed to improve student performance by implementing the *Tutorials in Introductory Physics* [1] in the recitation sections of the course. The *Tutorials* were chosen because they are a proven set of inquiry-based instructional materials which help students develop important physics concepts and reasoning skills [3]. We also had prior experience teaching similar instructional material contained in *Physics by Inquiry* [4].

In this paper we investigate how student understanding may be affected by the manner in which the tutorials are taught and compare the effectiveness of the tutorials with that of a traditional problem solving lecture style recitation. It is valuable to study which factors are crucial in effectively implementing the tutorials, since instructors who have not attended a University of Washington tutorial workshop may attempt to implement the tutorials in different manners, such as using them without Socratic dialogue or as individual worksheets. Also, limits on availability of TAs or time for training sessions may prevent some schools from implementing the tutorials in an ideal fashion. It then becomes a question as to how significant a proper implementation is to the success of the tutorial. Finally, the study will address the concerns of some of our non PER faculty colleagues who have doubts that the tutorials are actually more effective than traditional recitations.

We have previously shown that student conceptual understanding may be affected by the TAs' ability to implement the tutorials [5]. However, it is difficult to unravel the many factors that may affect student understanding in a multiple section course where students have different lecture and recitation instructors. The investigation described in this paper is a controlled comparison of student conceptual understanding of a topic after the students have been taught using different methods in a recitation class.

OBJECTIVES AND METHODS

The purpose of our study is to evaluate which teaching methods would be the most effective for recitation classes associated with lectures in introductory physics courses. The evaluation is based on student conceptual understanding which is measured by pretests and posttests given before and after recitation classes that are taught with different instructional methods.

General Physics is the University of Cincinnati's three-quarter long calculus-based physics course. The study was performed during the first quarter which covers mechanics. The first quarter course typically contains about 450 students with four lecture classes of 100-125 students meeting three times per week, taught by physics professors. Each lecture has weekly recitation classes of 20-25 students, taught by graduate teaching assistants (TAs) using the *Tutorials in Introductory Physics.* In addition to the TAs, advanced undergraduates are used as peer instructors to assist in teaching the recitation classes.

Weekly recitation training sessions are conducted for the TAs and peer instructors similar to the sessions developed by the Physics Education Group at the University of Washington. During each training session the participants take the tutorial pretest and complete the tutorial worksheets in cooperative learning groups. The TAs and peer instructors need this opportunity to understand the inquiry structure of the tutorial. They also learn to lead the student through the tutorial by asking appropriate questions.

The students in the recitation classes work in cooperative learning groups on the tutorial worksheets and activities. The recitation instructors are expected to continually interact with the students during recitation and especially at checkpoints placed at appropriate points in the tutorial worksheets. During the checkpoints the instructor asks various members of the group to explain their answers and reasoning on the tutorial worksheets. The checkpoints keep the groups on task and make them carefully consider their explanations. The instructors are taught not to directly answer the questions of the students but to use Socratic dialogue to lead the students to correct understanding. The faculty members in charge of the tutorials visit the recitation classes and evaluate the TA's performance, according to the number of interactions they have with the student groups and how they use Socratic dialogue during the checkpoints. Many recitation instructors perform satisfactorily, but some instructors only interact minimally with the students, merely giving the students the correct answers at the checkpoints, and need frequent reminders to use Socratic dialogue.

We decided that the best way to evaluate student understanding with different styles of instruction was to teach the recitation class outside of the course, since it would be unfair to impose an inferior method of instruction on some students. The study was thus arranged as part of an optional extra credit opportunity for all students in the course. Students were informed that they could volunteer to participate in a research study which would evaluate various styles of recitation classes. Their participation in the study required them to attend a recitation class which was not part of the course. As a volunteer they received extra credit points based only on their participation. Students who did not volunteer for the research study were offered the opportunity to receive the same amount of extra credit by doing an extra online homework assignment. The students who volunteered for the research study were randomly assigned to one of the four styles of recitation classes based their schedule.

The recitation study was performed during the seventh week of the first quarter of General Physics in the winter quarter of 2005. Of the 390 students who completed the course, a total of 272 students participated in the study.

The four styles of recitation classes were: (1) a traditional lecture, (2) students working individually using the tutorials, (3) students working in cooperative learning groups of three or four using the tutorials and (4) students working in cooperative learning groups using the tutorials with instructors performing checkpoints using Socratic dialogue. Style (1) was the only method that did not use the tutorials as written in the textbook. In this case the material in the tutorial was rewritten as problems with numerical answers. The instructor then presented the problems and the solutions at the blackboard and stated the conceptual results that the students should conclude from the example problems. This style was similar to traditional recitations where textbook problems are solved by an instructor. In style (2) the students worked alone. At the checkpoints the instructors gave the students an answer key for them to self-check their work. This style was to evaluate how well the students would perform using inquiry-based activities without the benefit of working within a cooperative learning group and without the aid of instructor dialogue. For style (3) the students performed the tutorial within cooperative learning groups but, as with style (2), the instructors only provided answer keys at the checkpoints without any dialogue. This method was used to evaluate how well students would learn in groups without the benefit of instructor dialogue. Style (4) used our normal method of teaching the tutorials with cooperative learning groups and instructors using Socratic dialogue at each checkpoint. The class was taught by an experienced TA and an undergraduate student, who were proficient in using Socratic dialogue. Two sessions were held for each of the four styles of recitation classes.

The tutorial activity *Changes in energy and momentum* was chosen for our study because it covers topics which students have difficulty understanding and was not scheduled as part of the regular course. This tutorial helps students develop a better understanding of how to apply the work-energy theorem and the impulse-momentum theorem to determine the final kinetic energy and momentum of objects. Another advantage of the tutorial was that we could compare our results with the published pretest and posttest results from the Physics Education Group at the University of Washington [6].

The pretest for the recitation classes was the same pretest used by the University of Washington [6] and the pretest provided in the Instructor's Guide for the tutorials [7]. The pretest shows two carts of different mass initially at rest on a frictionless horizontal table that are pushed by equal constant forces between the starting mark and a second mark on the table (see figure 1). After passing the second mark, the force on the cart is taken away and the cart glides freely. The students are asked if the less massive cart's kinetic energy and momentum are greater, less than, or equal to the kinetic energy and momentum of the more massive cart after both carts pass the second mark. The students are also asked to explain their answers.

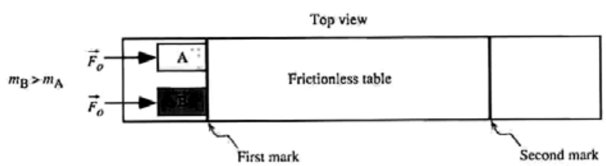

FIGURE 1. Diagram used in all recitations for the pretest.

The posttest contained two questions which were the same as those presented by the Physics Education Group at the University of Washington [6]. The first posttest question uses the same physical setup as the pretest but now the two carts are pushed from rest on a frictionless horizontal table by equal forces for equal time intervals instead of equal distances. The students are asked if the less massive cart's kinetic energy and momentum are greater, less than, or equal to the kinetic energy and momentum of the more massive cart at the end of this time interval and to provide explanations for their answers. The second posttest question shows two carts of unequal mass, A and B, on frictionless parallel tracks (see figure 2). Both start from rest and are pushed by equal constant forces until they cross the finish line. The more massive cart A starts behind cart B and the force acting on cart B does not begin until cart A passes it. Both carts cross the finish line at the same time with cart B traveling faster than cart A. The students are asked if the final momentum and the final kinetic energy of cart A is greater than, less than, or equal to the momentum and final kinetic energy of cart B, and to provide explanations for their answers.

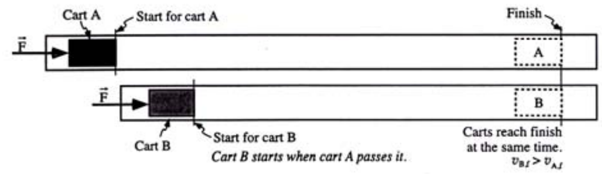

FIGURE 2. Diagram used in all recitations for the second posttest question.

RESULTS AND CONCLUSIONS

The pretest scores for the correct kinetic energy comparison and the correct momentum comparison are listed in Table 1 for each style of recitation. Only students with both a correct answer and correct explanation are listed. The work-energy theorem had been previously presented in lecture but the impulse-momentum theorem had not.

TABLE 1. Student performance on the pretest questions.

Recitation Style	Correct kinetic energy comparison	Correct momentum comparison
Style 1 (N =75)	25 %	1 %
Style 2 (N = 76)	29 %	3 %
Style 3 (N = 58)	21 %	0 %
Style 4 (N = 63)	22 %	0 %

A correct explanation for the comparison of the kinetic energy consisted of using the work-energy theorem, $F\Delta x = \Delta K$, to show equal kinetic energy changes (ΔK) for both carts. The correct explanation for the momentum comparison consisted of stating that cart B had a greater momentum by applying the impulse-momentum theorem, $F\Delta t = \Delta p$. Although rare, several students demonstrated correct understanding by solving for the kinetic energies and momenta using kinematics equations.

The pretest results for each style are similar with correct comparison scores for the kinetic energy ranging from 21% to 29% and for the momentum comparison ranging from 0% to 3%. The results of t-test comparisons of the ratios of correct answers for each style indicate that statistically (p-values > 0.05) the students in each style had a similar initial understanding of the topics. As a second comparison, the exam scores of each student were obtained and the average exam scores for each style group were also found to be similar. The low scores for the momentum comparison may be because the impulse-momentum theorem had not yet been covered in lecture class. Our pretest results, compared to the scores obtained by the Physics Education Group at the University of Washington (15% and 5%, respectively) [6], are higher for the kinetic energy comparison and lower for the momentum comparison.

Our scores for the two posttest questions are shown in Tables 2 and 3. The scores for the kinetic energy and the momentum comparisons for both questions were about twice as large for students in style (4) than those of the other three styles of recitations. The higher scores for style (4) in all four responses are statistically significant (p-values < 0.01), based on ratio t-test comparisons with styles (1), (2) and (3). The scores for styles (1), (2) and (3) are all statistically comparable, based on t-test ratio comparisons, except that the kinetic energy score for style (3) on posttest 2 is low compared to the other styles.

TABLE 2. Student performance on posttest question 1.

Recitation Style	Correct kinetic energy comparison	Correct momentum comparison
Style 1 (N =75)	16 %	20 %
Style 2 (N = 76)	12 %	11 %
Style 3 (N = 58)	12 %	21 %
Style 4 (N = 63)	35 %	43 %

TABLE 3. Student performance on posttest question 2.

Recitation Style	Correct kinetic energy comparison	Correct momentum comparison
Style 1 (N =75)	32 %	19 %
Style 2 (N = 76)	26 %	16 %
Style 3 (N = 58)	12 %	12 %
Style 4 (N = 63)	64 %	38 %

The low posttest scores for styles (1), (2) and (3) indicate that few of these students gained an understanding of how to correctly apply the work-energy and the impulse-momentum theorems in a new context. The higher kinetic energy comparison scores for posttest question 2 compared to posttest question 1 may be because the work-energy theorem is easier to apply in posttest question 2. Our posttest scores for style (4), based on a t-test comparison of the ratios of correct answers, are statistically consistent with the results (35% and 50%,respectively for posttest 1; 30% and 45%, respectively for posttest 2) obtained at the University of Washington [6], except our kinetic energy score on posttest 2 is higher.

The results of our study demonstrate that the tutorials are more effective than a traditional recitation and that the role of the instructor is crucial in teaching the tutorials. Using the inquiry-based tutorial alone as a worksheet is not very effective, as seen from the results of the style (2) recitation. Style (3) recitation was also ineffective, even though the students worked in groups. Our observations of student interactions indicate that this may be because they tended to accept the correct answers at checkpoints with little discussion of explanations. Our results show that it is necessary to have instructors conduct Socratic dialogue with the student groups to obtain gains in student understanding comparable to those obtained at the University of Washington. This emphasizes the importance of training recitation instructors in the use of Socratic dialogue and requiring its use when teaching the tutorials.

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