

A Study of Peer Instruction Methods with High School Physics Students

Karen Cummings^a and Stephen G Roberts^b

^a*Southern Connecticut State University, New Haven, CT 06515*

^b*Staples High School, Westport, CT 06515*

Abstract: This paper reports on the results of an experiment to test the use of a Peer Instruction (PI) pedagogical model in a small class, high school environment. The study reports findings based on a population of 213 high school students attending algebra based physics courses, both Honors and A level, taught by 5 different instructors. The results show a correlation between use of Peer Instruction and improved student conceptual understanding, as demonstrated by gains on a pre-/post- assessment instrument (FCI). However, there also appears to be a number of other factors that strongly influence the resulting gains. In addition to instructor differences, the data seem to indicate that students who are more “physics-inclined” and can answer questions correctly prior to instruction and prior to any Peer Instruction discussion subsequently achieve higher gains as measured by the FCI. While this is to be expected, the use of normalized gains is intended to mitigate this result, but it appears to be prevalent nonetheless. This raises questions as to what degree the FCI gains can be attributed to the use of Peer Instruction, to teacher differences, to student ability level or to simply increased familiarity with the question types presented on the FCI.

Keywords: Peer-instruction, High school, Physics, Conceptual Learning, Variations

INTRODUCTION

Prior to the 1980’s, science education in America was dominated by a theory that viewed students as vessels, to be filled with knowledge by their instructors. This led to the typical pedagogical style that dominates physics education, the attempt to transfer information rapidly by means of instructor dominated lectures and modeling of problem solving. Over the course of the last two decades, mounting evidence has indicated that students retain very little knowledge of information presented in this manner¹, even if they are able to replicate problems on exams. This in turn led to research studies in physics education which revealed that instructional approaches that actively engaged students were far more effective in improving conceptual understanding.²

Unfortunately, seemingly little of the pedagogy or instructional materials developed to address this issue have made it into high school physics classrooms. Traditional instructional methods continue to dominate, perhaps because the education research is not taken seriously or because many of the solutions involve extensive changes to an entire course and so are not easily implemented. One instructional technique that responds to the research on student learning yet does not require an unreasonable level of effort to implement is Peer Instruction (PI).

A considerable body of research exists that documents the gains in conceptual learning experienced by students who experience PI in post secondary, large scale classes.³ However, little work has been done to investigate the benefits of Peer Instruction in smaller, secondary school classrooms, where Socratic and other teaching methods can engage a majority of students already. In an attempt to measure potential gains in this environment, one of the authors (SR) performed a small scale (2 classes, 31 students) preliminary study to measure the gains in conceptual understanding when PI is used in a high school classroom.

The results of that study showed a strong correlation between use of Peer Instruction and improved student conceptual understanding. It also showed a small but positive impact on student ability to problem solve, as measured by student performance on a common unit assessment.

However, that study had a number of weaknesses. It was performed by one instructor only, the gains were not measured with a standard assessment tool, many of the ConcepTest questions used were developed by the author and contained some weakness themselves and there was not a strong correlation between the content covered by the ConcepTest questions and the items on the assessment tool. Finally, the voting data was collected by use of index cards and manually

tabulated by the instructor, which may have impacted the effectiveness of the technique.

That study also raised a number of questions:

- What would be the impact of a variety of instructors, with unique instructional approaches and experience?
- Student gains in the preliminary study varied significantly. Is there an identifiable factor or factors that could explain this variation?

The current study was designed to address some of the weaknesses of the previous work and to begin to answer the questions raised above. A standard research based assessment tool was used to measure conceptual understanding (the FCI), the study was performed with 5 different instructors, proven ConcepTest questions were used and selected to closely correlate with questions on the pre/post assessment tool and data was collected by use of a classroom response system (CRS) or ‘clickers’.

In addition to measuring gains achieved on the FCI, an attempt was made to measure the degree of correlation between the gains of individual classes and their performance on the pre-assessment and/or their performance on ConcepTest questions. The impact of different instructors was also investigated.

METHODOLOGY

The research population consisted of ten separate classes of students attending algebra-based, introductory physics courses at a suburban high school in Connecticut. The classes ranged from 17-24 students each and were separated into 3 classes of Honors and 7 classes of A level students, totaling 213 students. Five different instructors were involved in the study, each bringing unique experience and teaching styles. Independent of this example, none of the instructors involved employ strictly “traditional” teaching techniques, so students had been exposed to Socratic or verbally engaging teaching styles.

Five groups received the same instruction they would have in any other semester. For comparison to the PI group, this group is referred to as having had *traditional instruction*, although as stated above the method employed by the teachers was not the typical passive lecture / problem solving approach. The other five groups were taught the exact same content using a Peer Instruction approach (the PI method is documented below).

The content area was an introduction to forces and motion (Newton’s laws). To assess student conceptual understanding, the Force Concept Inventory (FCI)⁴ was used, given to students both pre-instruction and post-instruction.

Peer Instruction is characterized by the use of ConcepTests (CT) which are sort, conceptual questions related to the topic being discussed. These questions are designed to uncover common student misconceptions. A typical class period involved a short discussion on a key concept, followed by a ConcepTest posed to students on the class projection system. Students would consider the question individually, then indicate their answer by use of individual ‘clickers’ in a classroom response system (CRS). The CRS would tabulate and display a graph of student answers. If there was considerable disparity in student answers, or general agreement, but on a wrong answer, students were given the opportunity to discuss their reasoning with neighboring classmates. After 2 minutes or so, students were asked to record their new answers. Some changed their mind based on the conversation with peers. The correct answer was then explained and discussed and the instructor moved on to another concept. The CRS also saved a record of all student responses, so that answers to ConcepTests could be later analyzed.

RESULTS AND DISCUSSIONS

Pre/Post Assessment Results

Gains in conceptual understanding is reported here as a normalized gain $\langle g \rangle$, based on percentage correct pre- and post-instruction ($\langle S_{pre} \rangle$ and $\langle S_{post} \rangle$ respectively) where

$$\langle g \rangle = 100x \frac{\langle S_{post} \rangle - \langle S_{pre} \rangle}{100\% - \langle S_{pre} \rangle} \quad (1)$$

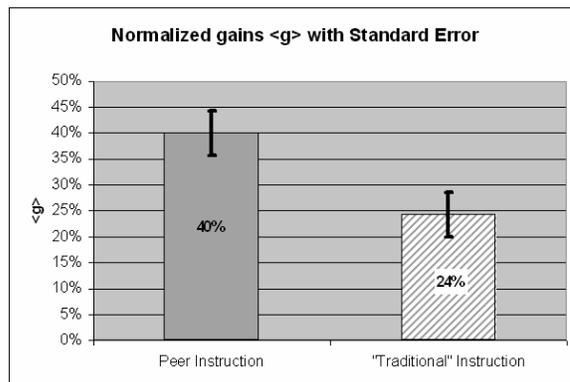


Figure 1: Pre/Post Assessment aggregate Results

Results show that improvements in student understanding were achieved when the PI method was used; with the test group showing a 40%

normalized gain, compared to 24% gain achieved by the control group, as seen in Fig. 1 above.

However, there were significant variations in gains achieved, depending on the level of the course, as shown in Fig. 2. Gains for A level classes improved 10% when PI was used, while gains for honors level classes improved by 16%. This result suggests that factors other than simply the use or lack of use of PI may be impacting student gains.

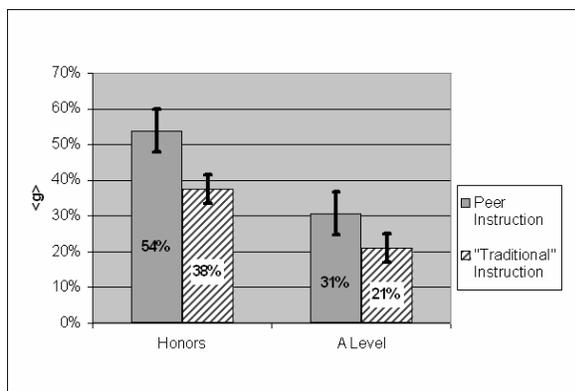


Figure 2: Normalized gain comparison by level, with standard error indicated

Factors producing variation in results

Student performance on ConcepTests differed by teacher and is shown in Fig. 3. To better understand what specific factors might be causing these differences, some information about each teacher is listed below.

Teacher A has 5 years of physics teaching experience and, as an author of this paper (SR), has the greatest degree of familiarity with Peer Instruction. All other teachers had just a brief introduction to PI prior to the study by the author. All courses taught by the teachers are listed below, but only A level and Honors courses were part of this study. Some teachers teach more than one section of a course.

Teacher A teaches fulltime, 3 different courses, Honors physics, AP physics and Aerospace.

Teacher B has 0 years of physics teaching experience and teaches part-time 1 course, Honors physics.

Teacher C has 12 years of physics teaching experience and teaches fulltime 3 different courses, AP physics, A level physics and B level physics.

Teacher D has 35 years of physics teaching experience and teaches fulltime 2 different courses, A level physics and B level physics.

Teacher E has 0 years of physics teaching experience and teaches fulltime 2 different courses, A level physics and science research.

This variation with instructor may not be surprising, especially given that they teach different student populations (Honors, A level and B level students). Yet, it may be important to note that teachers with the lowest numbers of students who ever get a right answer on the ConcepTests are also those with the lowest gains as shown in Fig. 4. In fact, two of the teachers (C and D) have so few students who ever get the right answer to the ConcepTests (52% and 40% respectively) that the technique's developers would likely argue that the questions chosen are not appropriate for that specific class. This instructor influence is quite correctable. It is also interesting to note that the teacher with the highest gain had no prior teaching experience and the teacher with the lowest gain had the most teaching experience. This may indicate that it is hard for very experienced instructors to change their teaching style.

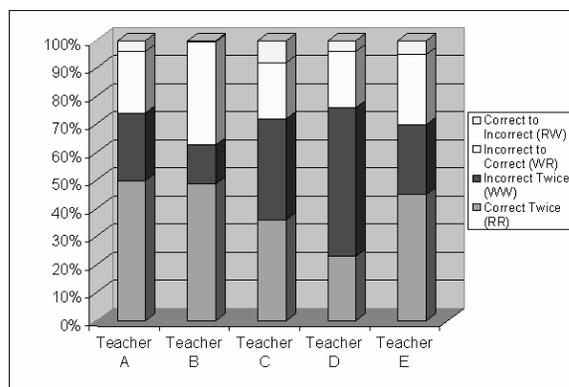


Figure 3: ConcepTest % correct, prediscussion and postdiscussion, by teacher

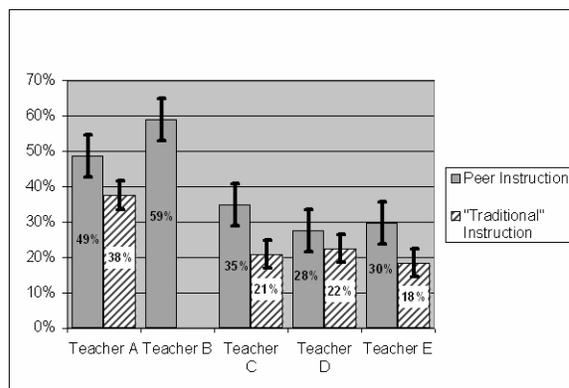


Figure 4: Normalized gain comparison by teacher, with standard error indicated

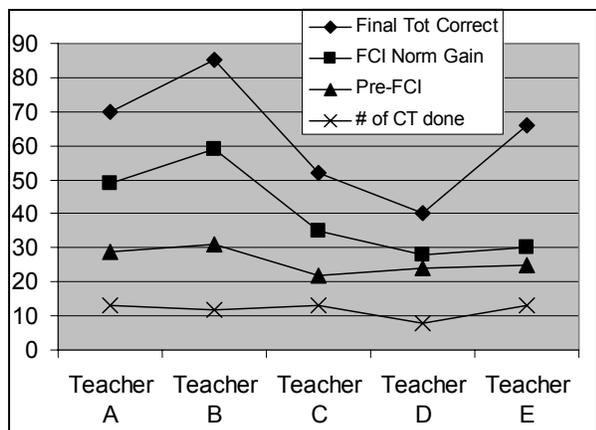


Figure 5: Various factors that might influence normalized gain by teacher.

Figure 5 above examines additional factors that could impact the degree to which a class may benefit from the use of PI. It shows some degree of correlation between students' performance on the pretest and normalized gains measured by the FCI. The correlation coefficient for these two sets of data is 0.89. There also appears to be a correlation between the percentage of students who answer ConcepTests correctly (Final Tot. Correct) and normalized gains. The correlation coefficient for these two sets of data is 0.85. The correlation coefficient between the number of correct ConcepTests and pre-test FCI score is 0.70. All the teachers seem to use about the same number of ConcepTests during instruction (# of CT done).

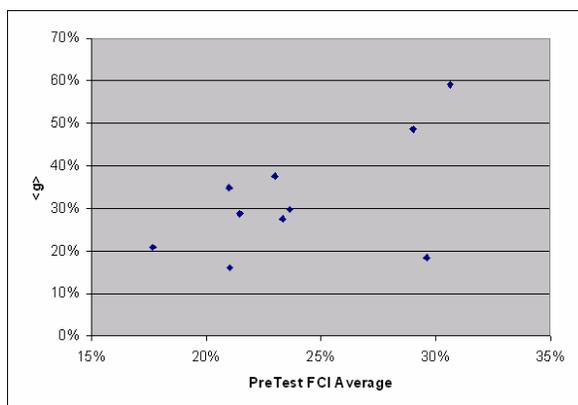


Figure 6: Correlation between normalized gain and Pre-test FCI average for each of the 10 classes studied.

To better measure the degree of correlation between normalized gains and pretest performance, these data are shown for each of the ten classes involved in this study in Fig. 6. A correlation

coefficient of .64 was calculated for these two sets of data.

CONCLUDING COMMENTS

The results of this study replicate those of prior studies which show improvements in normalized gains on the FCI when Peer Instruction is employed. In addition, this study adds data on the use of Peer Instruction in the high school classroom and with multiple instructors teaching two different level courses at the same institution.

Our data indicate that conceptual learning gains vary with teacher. There were two new teachers involved in the study. One achieved the highest gain of the group. The other had a gain approximately equal to the lowest of the group which was associated with the teacher with the most experience.

Gains also varied with student ability level as measured by level of the course they were taking, pre-test FCI score and the ability to formulate correct answers to ConcepTests either before or after group discussion. However, two instructors in the study had such large percentages of students with incorrect answers to the ConcepTests that many researchers familiar with the Peer Instruction technique would argue that the questions chosen were inappropriate for use with that particular student population. These two instructors taught the lower level course and had students lower pre-test scores. This is important because it may indicate that correlations between low gains in conceptual understanding and low pre-test scores or class level results, at least in part, from ineffective adaptation of the Peer-Instruction technique to the specific population in a way that is quite easily corrected. This issue warrants additional study.

¹ For example, see I. Halloun and D. Hestenes, "The initial knowledge state of college physics students," *Am. J. Phys.* **53** (11), 1043–1055 (1985); L.C. McDermott, "Millikan Lecture 1990: What we teach and what is learned—Closing the gap," *ibid.* **59**, 301–315 (1991) as referenced in ref 3.

² R. R. Hake, "Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.* **66** (1), 64–74 (1998).

³ Catherine Crouch and Eric Mazur, "Peer Instruction: Ten years of experience and results," *Amer. J. Phys.* **69** (9), 970-977 (2001)

⁴ D. Hestenes, M. Wells and G. Swackhammer, "Force Concept Inventory," *Phys. Teach.* **30** (3), 141–151 (1992).