AC 2009-501: EFFECTIVENESS OF USING PERSONAL-RESPONSE SYSTEMS IN A CONCEPTUAL PHYSICS COURSE

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Effectiveness of Using Personal Response Systems in a Conceptual Physics Course

Abstract

We report the results of a study investigating the effectiveness of using a Personal Response System (clickers) in a conceptual physics course for non-science majors. In order to determine their effectiveness, clickers were used while teaching some concepts and not used while teaching others. We used the Force Concepts Inventory (FCI) as a pre-test and post-test to measure learning gains because most of the questions on the FCI test only one concept. By comparing learning gains for those concepts taught using the clickers with those taught without using them, the effectiveness of clickers in this type course was inferred.

The concepts tested were Newton's three laws. In Fall 2007 clickers were used to teach the first and third laws, and in Fall 2008 they were used to teach only the second law. We found a statistically significant difference in the pre-test and post-test mean percent correct for questions pertaining to the first and third laws whether clickers were used or not. The percent gains for questions pertaining to the first and third laws were greater when the clickers were used; however, they were only significantly greater for the third law. No significant difference was found for either the mean percent correct or the percent gain for questions pertaining to the second law, whether or not clickers were used. The percent gains for the entire FCI were greater when the clickers were used to teach the first and third laws compared to when they were only used to teach the second law, but this difference was not quite significant ($p<0.066$). This suggests that using clickers in a conceptual physics course does improve learning force concepts, especially concepts related to Newton's 3rd Law. It also suggests that the first and third laws are more easily understood conceptually than the second law.

I. Introduction

Personal Response Systems (clickers) have been shown to improve learning in various classroom settings when effectively used.[1] I implemented the use of clickers in my conceptual physics course because I already used various methods to encourage student engagement in my classroom,[2] and this seemed like a good method as well. After incorporating clickers into my instruction and using them for two semesters, I began to wonder whether or not they were having a positive effect on learning in my conceptual physics classroom. They were certainly facilitating students' engagement with the concepts being taught, and anecdotal evidence suggested that they were improving learning, but I wanted more concrete evidence in order to justify the cost of the clickers for students. The Center for the Scholarship of Teaching and Learning at our institution offers assistance and small grants to faculty to study how their pedagogy is linked to learning. I was awarded one of those grants, called the Scholarship of Teaching and Learning (SoTL) grant, and became a SoTL Fellow. This study was designed to answer my question quantitatively.

Many institutions teach a conceptual physics course for non-science majors that students may take to fulfill their general education requirement in physical science. The textbook we use is

Conceptual Physics by Paul Hewitt, although there are several textbooks available for this type of course. At our university, few academic majors require this course, so most students take it because it fits their schedule rather than because they must or because they are interested in physics. In addition, only one section of the course is taught each semester in large lecture format with from 60 to 80 students in lecture. It is always a challenge in large lecture courses to get students to genuinely engage the content of a class session, but this is especially true for a course like this where student interest and motivation are relatively low. Adding to the challenge is the fact that the chairs in the lecture hall are fixed to the floor, so group interaction is very difficult. The purposes of using the clickers are to facilitate student engagement with the concepts being discussed in a more active way than does simply listening or taking notes and to provide feedback to the instructor on whether or not more time needs to be spent on particular concepts.

II. Methodology

During a typical session of this class, the clickers are used one to three times and in two distinct ways. First, at least one question is chosen before each class to use as a "clicker question." This may be over a concept from the previous class period or something from that day's class. Students are usually asked to answer the question on their own or occasionally after discussing it first with their neighbor. Students are given several choices for the answer that usually include "don't know" and "don't care." The distribution of answers that is displayed when time expires gives the instructor immediate feedback as to understanding of the concept. If the distribution of responses indicates that the majority of students understand the concept, students who chose a particular response are asked to explain their reasoning. The correct answer is then revealed by the instructor and briefly discussed. If the distribution of responses indicates that a significant fraction of the class does not understand the concept, students are given a brief time to discuss the question with their neighbor and then answer the question again. In most cases after this neighbor nudge, the distribution of responses indicates that the majority of students understand the concept. Again, before the correct answer is revealed and discussed, students choosing each response are asked to explain their reasoning.

The second way the clickers are used is in an ad hoc manner to engage students during the class session. Neither the timing nor the question is preplanned. The clickers simply serve as a way of shifting the energy in the classroom and reengaging students with the material under discussion. When the distribution of answers is displayed, the same procedures described above are used.

When the topics are taught without using clickers, similar teaching methods are used, except only a show of hands is requested so there is no quantitative feedback immediately provided other than what is gleaned by looking around. The level of activity when these topics are taught is similar to that when clickers are used, as are the other procedures described above such as using the neighbor nudge if the show of hands indicates it would be helpful.

Other active learning strategies are also used throughout the semester such as having students work in pairs on a short worksheet.

The FCI[3] was given on the second day of class and then again two weeks after the exam covering the pertinent topics. The choice of which topics to use clickers with and which topics not to was determined by looking at the FCI questions that cover each topic. On the FCI, questions 6, 7, 8, 10, 11, 17, 23, 24, and 25 test understanding of Newton's 1st Law, questions 8, 9, 21, 22, and 26 test understanding of Newton's 2nd Law, and questions 4, 15, 16, and 28 test understanding of Newton's 3rd Law.[4] Question 8 was excluded from our analysis since it covered both Newton's 1st and 2nd Laws.

In Fall 2007, Newton's 1st Law and Newton's 3rd law were taught using clickers, but Newton's 2nd Law was not; and in Fall 2008, Newton's 2nd Law was taught using clickers, but Newton's 1st and Newton's 3rd laws were not.

III. Results and Discussion

Figure 1 shows the mean percent of the questions pertaining to Newton's 1st Law answered correctly for both years. The difference between the pretest and posttest means is significant for both years; however, the difference is more significant for 2007 when clickers were used in teaching the first law compared to 2008 when they were not used. Figure 2 shows the mean percent of the questions pertaining to Newton's 2nd Law answered correctly for both years. The difference between pretest and posttest means is not significant for either year, whether or not clickers were used. Figure 3 shows the mean percent of the questions pertaining to Newton's 3rd Law answered correctly for both years. The difference between the pretest and posttest means is significant for both years; however, the difference is more significant for 2007 when clickers were used in teaching the third law compared to 2008 when they were not used.

Figure 4 shows the percent gain for questions pertaining each of Newton's laws. The percent gains for questions pertaining to the first and third laws were greater when the clickers were used than when they were not used; however, they were only significantly greater for questions pertaining the third law. No significant difference was found in the percent gain for questions pertaining to the second law, whether or not clickers were used. In fact, understanding of the second law seems to have suffered.

The pretest mean percent correct, posttest mean percent correct, and percent gain for the entire FCI for the two years are shown in Figure 5. We see that the overall percent gain was smaller in 2008 when clickers were used only when teaching Newton's 2nd Law compared to 2007 when they were used when teaching the first and third laws. Although the difference in the two percent gains is not strictly speaking significant ($p<0.066$), it is nearly so.

At about week ten of the semester, a questionnaire was given to obtain feedback from students on various aspects of the class. To the question "Do you think using the clicker questions during each class period helps you learn the physical concepts better?" 68% said using clickers definitely helped and another 13 % said using them helped some.

The results of this study suggest that using clickers in a conceptual physics course does improve the learning of force concepts, especially concepts related to Newton's 3rd Law. They also

suggest that Newton's 1st Law and Newton's 3rd Law are much more easily understood conceptually than is Newton's 2nd Law.

IV. Conclusions

One obvious conclusion is that more emphasis needs to be placed on Newton's 2nd Law in teaching this course. In addition, the results from the overall FCI seem to indicate that overall learning of force concepts is improved by using the clickers.

References

1. Beatty, I. D., W. J. Gerace, W. J. Leonard, and R. J. Dulfresne, "Designing effective questions for classroom response system teaching," *Am. J. Phys.* Vol. 74, No. 1, January 2006, pp. 31-39. See also references therein.

2. Mazur, E., *Peer Instruction: A User's Manual*, Prentice Hall: Upper Saddle Ridge, NJ, 1997.

3. Hestenes, D, M. Wells, and G. Swackhamer, "Force Concept Inventory," *The Physics Teacher*, Vol. 30, March 1992, pp. 141-158.
   See also http://modeling.la.asu.edu/R&E/Research.html.

4. See revised Table I in Reference 3 above at http://modeling.la.asu.edu/R&E/Research.html.

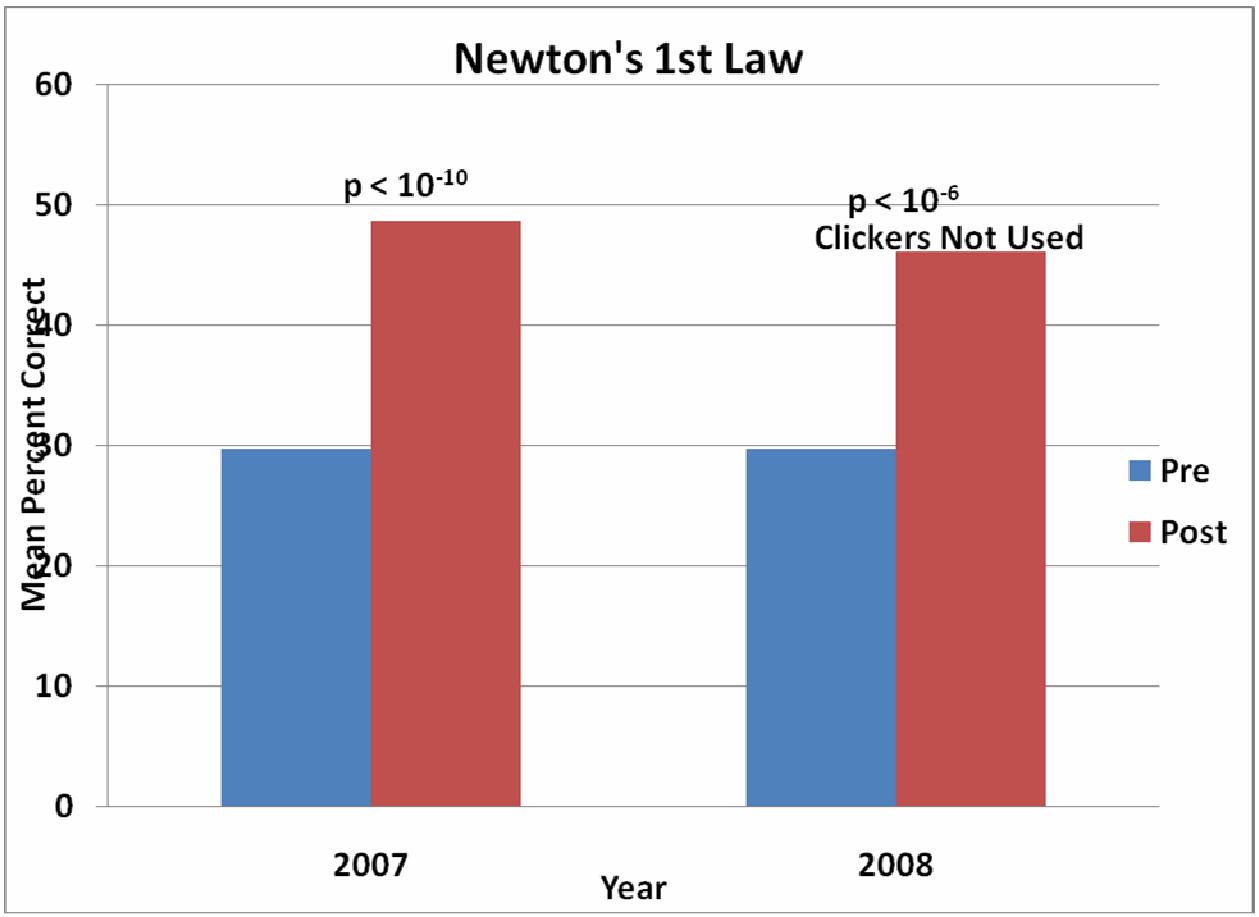

Figure 1. The mean percent of the questions pertaining to Newton's 1st Law answered correctly for both years. The difference between the pretest and posttest means is significant for both years; however, the difference is more significant for 2007 when clickers were used in teaching the first law compared to 2008 when they were not used.

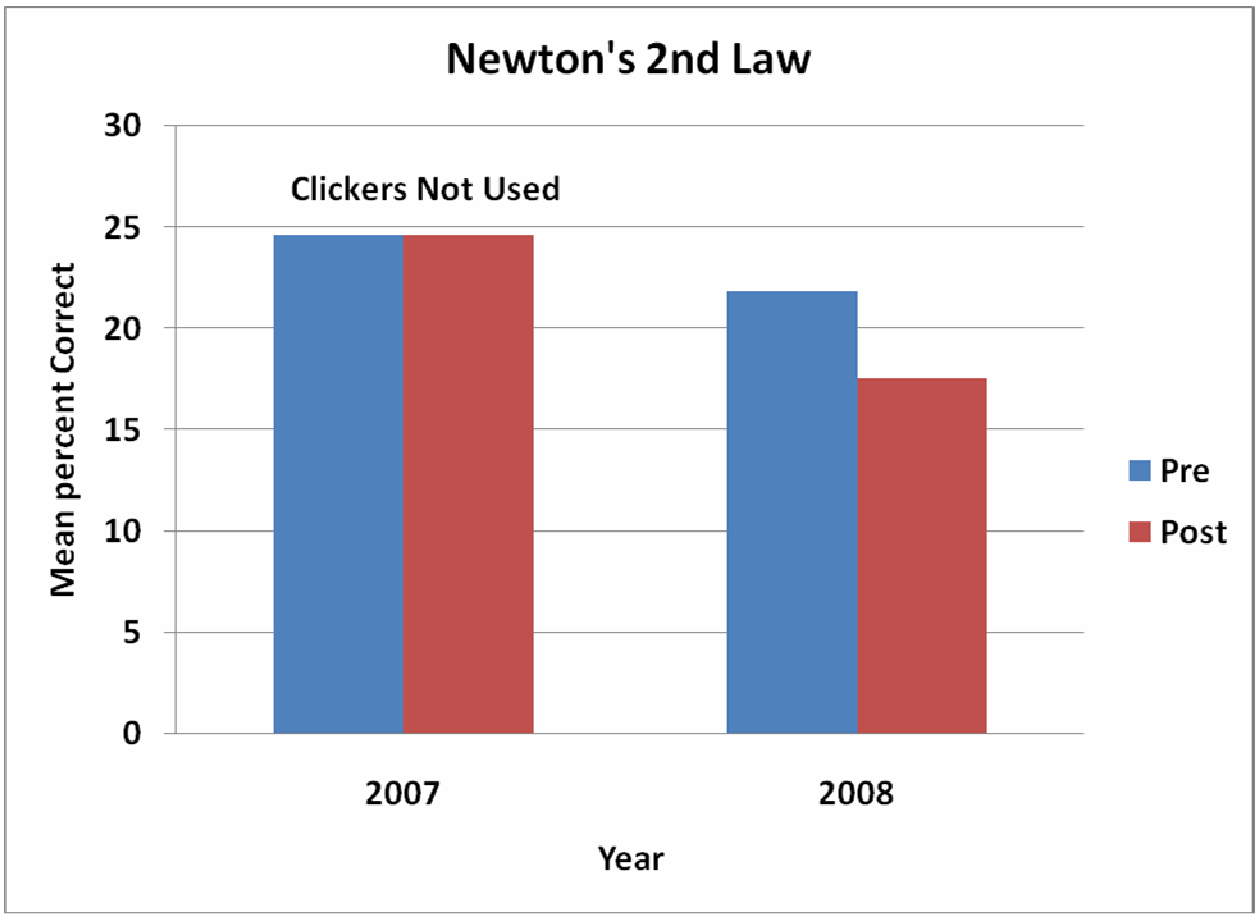

Figure 2. The mean percent of the questions pertaining to Newton's 2nd Law answered correctly for both years. The difference between pretest and posttest means is not significant for either year, whether or not clickers were used.

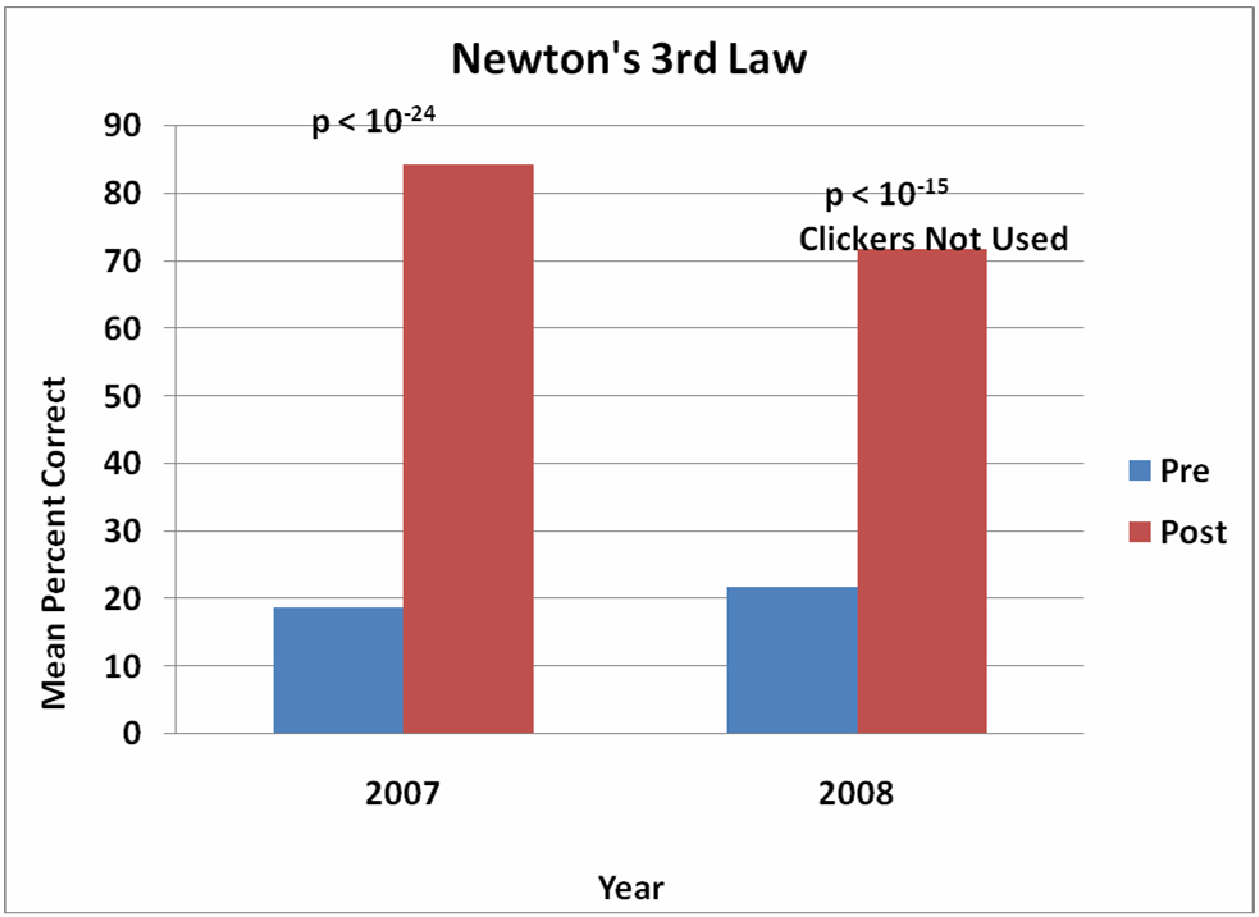

Figure 3. The mean percent of the questions pertaining to Newton's 3rd Law answered correctly for both years. The difference between the pretest and posttest means is significant for both years; however, the difference is more significant for 2007 when clickers were used in teaching the third law compared to 2008 when they were not used.

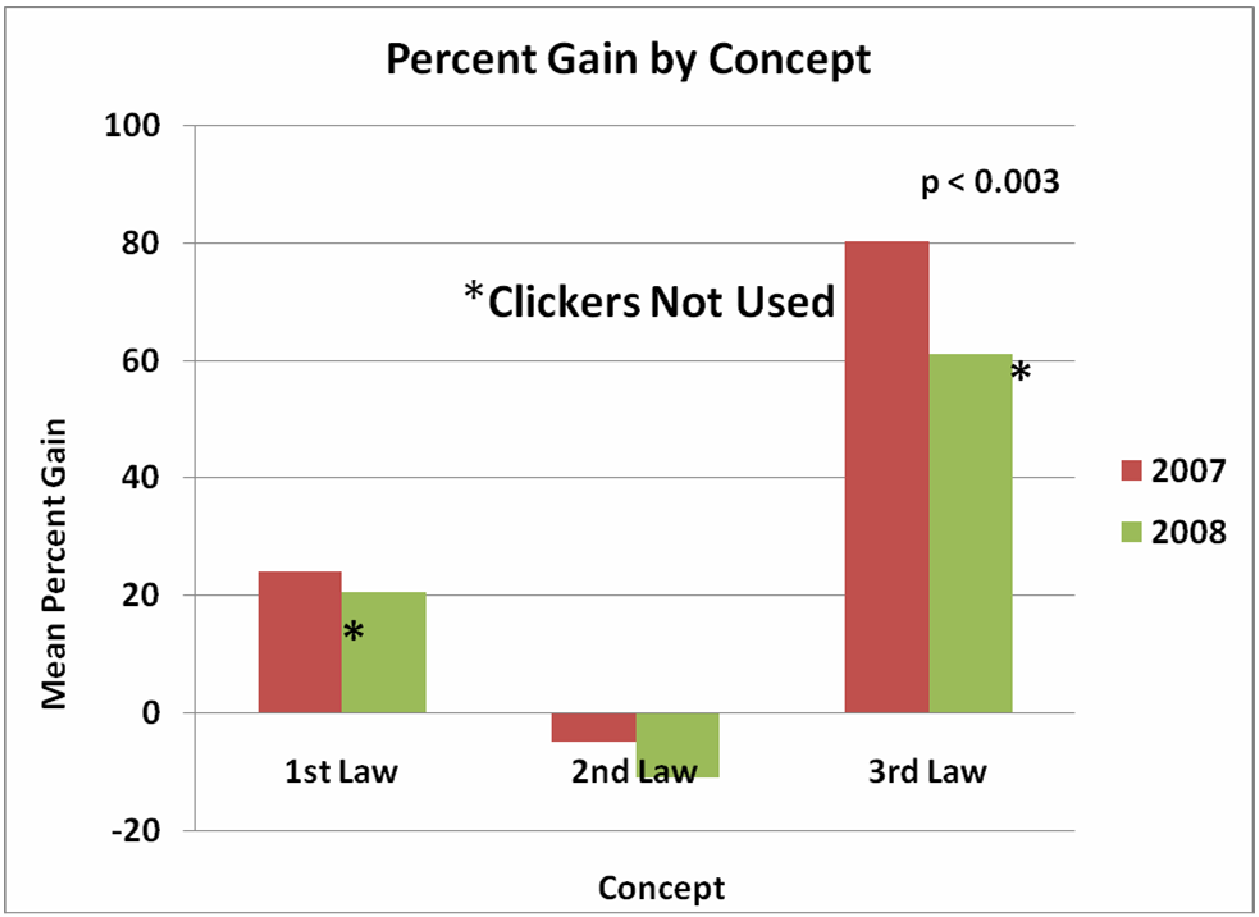

Figure 4. The percent gains for questions pertaining to the first and third laws were greater when the clickers were used than when they were not used; however, they were only significantly greater for questions pertaining the third law. No significant difference was found in the percent gain for questions pertaining to the second law, whether or not clickers were used. In fact, understanding of the second law seems to have suffered.

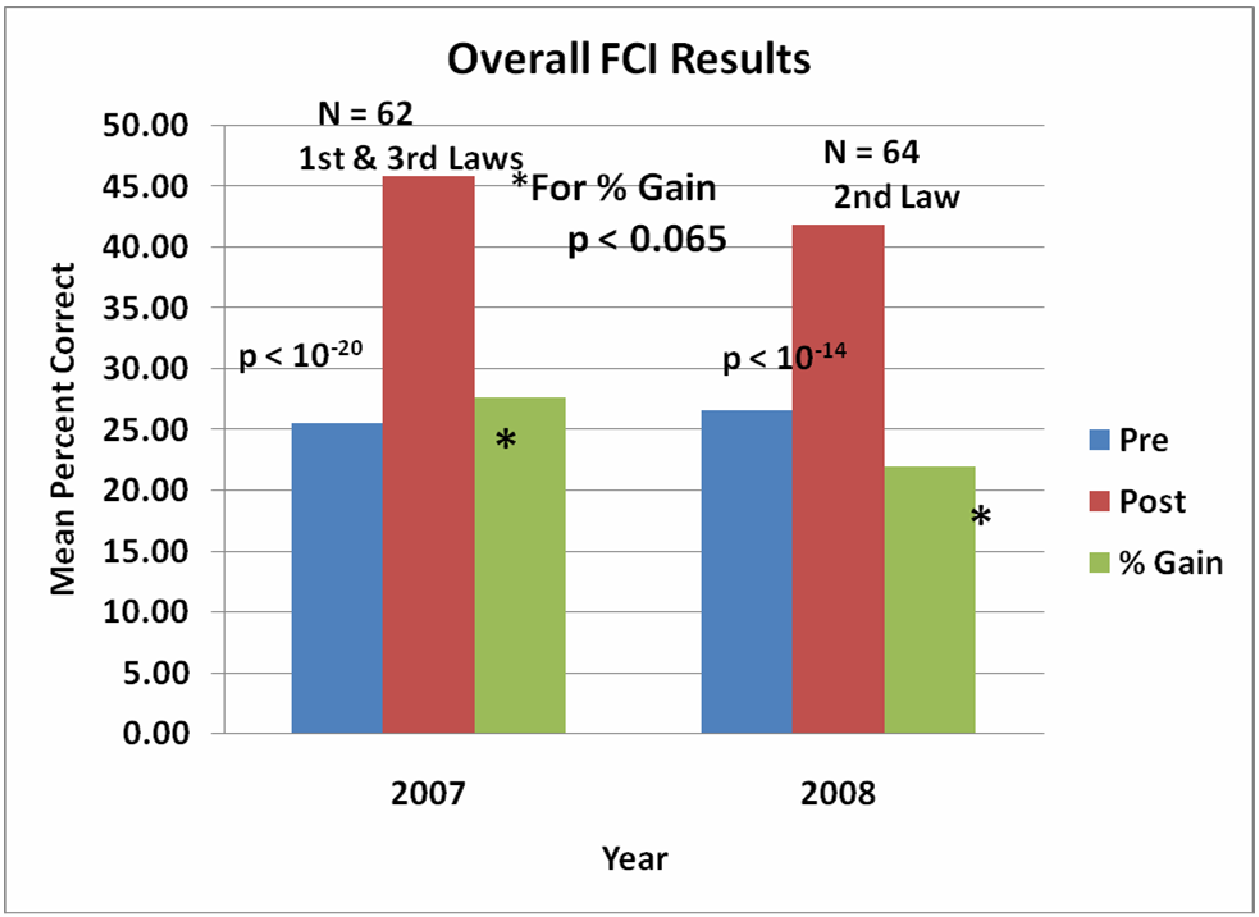

Figure 5. The overall percent gain was smaller in 2008 when clickers were used only when teaching Newton's 2nd Law compared to 2007 when they were used when teaching the first and third laws.