A Study of the Effectiveness of Using PER-Based Reforms in a Summer Setting

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Introduction/Background

Physics Education Research (PER) is a sub-discipline of physics that focuses on developing research-based models and practices of teaching, learning, and student understanding. As a result of physics education research, many course transformations have been developed in an effort to improve students' overall understanding of physics. Some of such transformations include: Peer Instruction, Matter and Interactions, Tutorials in Introductory Physics, SCALE-UP and many others[1]. It has been found that these transformations are very successful in terms of increasing student content knowledge, making conceptual gains double that of traditional classroom settings[2]. Transformed classrooms differ from traditional classrooms in the way learning takes place. In a traditional classroom the instructor lectures to a student who sits quietly and takes notes occasionally asking a question. The hope is that a transfer of knowledge from the instructor to the student will take place. In most transformed classrooms, the students are actively engaged in some way in the learning process.

Many of these classroom transformations have been proven to be particularly successful in large lecture introductory physics courses[2]. Because of this it would be interesting to know whether or not the success these PER-based transformations can be replicated beyond institutions where reforms were developed and if so, how this could best be done. The University of Colorado at Boulder (CU Boulder) has developed a model of a transformed introductory physics course and since the fall of 2003, has been carrying out on-going research with several goals: identifying causes of success (and failure) in these reformed classrooms, assessing the feasibility of repeating and sustaining reforms, and attempting to transfer of reforms to non-PER faculty[3 4]. From this research it has been found that:

1) There are multiple factors that affect success and failure in these transformed classes
2) It is possible to successfully repeat and sustain these reforms
3) It is possible to transfer reforms to non-PER faculty and achieve success

While these and other studies have produced many interesting results concerning transformed classrooms, they have focused on courses reformed during the school year. The summer term remains under studied. This raises the question: is this same success attainable in a summer course? If so, what factors contribute to success or failure in these settings?

Methodology

As aforementioned, the efforts of PER have produced many classroom transformations which have proven quite successful at improving students' conceptual understanding of physics. When CU Boulder began transforming their introductory calculus-based physics sequence, they included a combination of these PER-based physics reforms. Some of these reforms include electronic personal response systems, computer based homework systems, and in some cases a reformed text. The key to the CU Boulder reformed classroom, however is the reformed recitation[5].

The recitations used at CU Boulder are called *Tutorials in Introductory Physics* (*Tutorials*) and were created at the University of Washington. The idea behind *Tutorials* is to transform recitations in introductory physics courses by changing the materials used, classroom format, instructional role, and by promoting group work. This particular reform is one of the most researched and is ideal for implementation because it is relatively un-intrusive. It also places few demands on faculty in terms of time and fits nicely into the traditional institutional structure of an introductory physics course[2].

The current work focuses on a study conducted during the first summer session in 2006 term at CU Boulder. The objective of this study was to investigate the effectiveness of implementing *Tutorials*, which had already proven to yield good results in the fall and spring terms, in a summer semester. The course studied was PHYS 1110, CU Boulder's introductory calculus based mechanics course. The course consisted of approximately 60 students, and the reform tools used in the course had been used in past studies on the same course.

In order to analyze the effectiveness of implementing *Tutorials* two instruments were used. The first is known as the Force Motion Conceptual Evaluation (FMCE). It is a survey that is given at the beginning and end of a course and it is designed to measure conceptual understanding of Newton's laws, velocity, and acceleration. CU Boulder transformed classrooms to which data are being compared achieve an average gain of .57 on the FMCE.

The other instrument used is called the Colorado Learning Attitudes about Science Survey (CLASS). This survey is also given at the beginning and end of a course. It measures shifts in attitudes and beliefs (AB's) about physics and learning physics over the course of the semester. Answers to questions are given on a scale of 1 (strongly agree) to 5 (strongly disagree). Shifts are typically double digit negative even for reformed courses[2].

In addition to these two instruments, field notes were taken by the author during observations of the recitations. The author participated in some of the recitations in order to get a flavor for the classroom culture developed by these interactive recitations. Also, once the course was over, the TA was asked to recap her experience and compare it to that of being a TA during the fall and spring semesters. Additional data sources were collected to give a sense of the factors involved in determining the outcomes of this study.

For comparison, several PHYS 1110 courses from the school year were used. These semesters all implemented at least some of the same, or similar reforms to those used in the summer 2006 term. All courses compared used online homework systems, all used personal response systems, all except one used a PER-based text, and all except one used reformed recitations.

Data

FMCE

Figure 1 shows a comparison of the FMCE normalized gains achieved in several semesters with gains obtained in several other semesters along with the nation average on a similar conceptual survey. The first group of data to the far left is from two semesters in which tutorials were implemented with interactive engagement-1 (I.E.-1). In I.E.-1 the personal response systems were used as follows. After a concept was covered in lecture a question regarding this concept was immediately presented to the students. The students were then given time (and encouraged strongly) to consult classmates about these questions and then select their choice using the clicker.

The second set of data is labeled traditional recitations with I.E.-2. The term, traditional recitation, refers to the format of the recitations. As mentioned earlier, in a traditional recitation the students all sit at tables in a room facing a teacher and the teacher tries to impart as much of his/her knowledge on the student as they can. In I.E.-2 the personal response systems were used as follows. Once a concept was taught, as with I.E.-1 a student was immediately presented with a question concerning the concept taught. In this case however Peer Instruction (student discussion) was not emphasized.

The third data set is labeled summer with tutorials and I.E.-3. In I.E.-3 electronic personal response systems were used in the following way. A whole chapter was covered. Once the chapter was covered students were given a series of questions (usually 8 to 10) concerning concepts that were covered in the chapter. Peer instruction was sometimes used but not particularly encouraged. The variation in the gains among courses which used Tutorials is currently being studied[4].

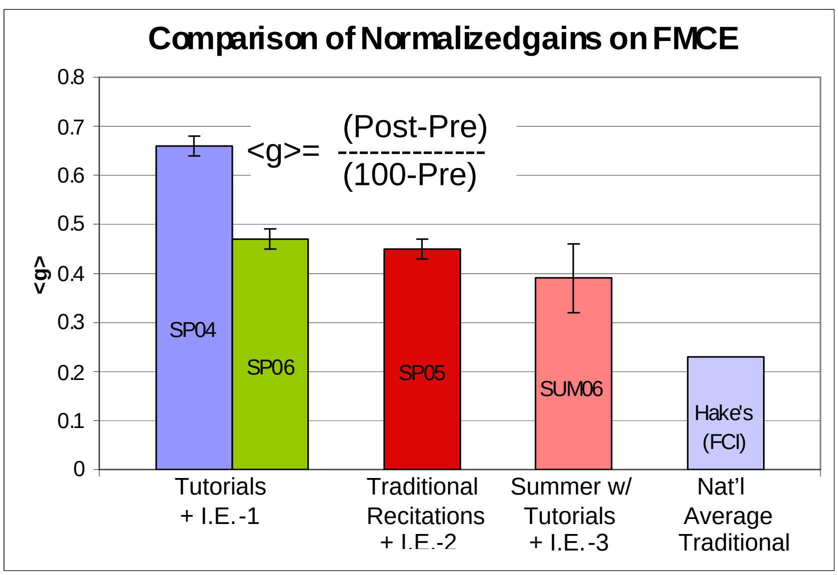

Figure1: Comparisons of normalized gains on the FMCE over several semesters and the National average on a similar survey.

CLASS

Figure 2 shows a comparison of CLASS shifts for several semesters. The shifts shown in the figure are a difference between the post score and the pre score on the survey. To the right of the graph are the pre scores corresponding to each semester. The spring 2004 semester has a positive shift in attitudes and beliefs. The next three semesters (Fa04, Sp05, Fa05) all have negative shifts in AB's of >5%. The last two semesters (Sp06, Sum06) all have fairly small negative shifts in AB's (<5%).

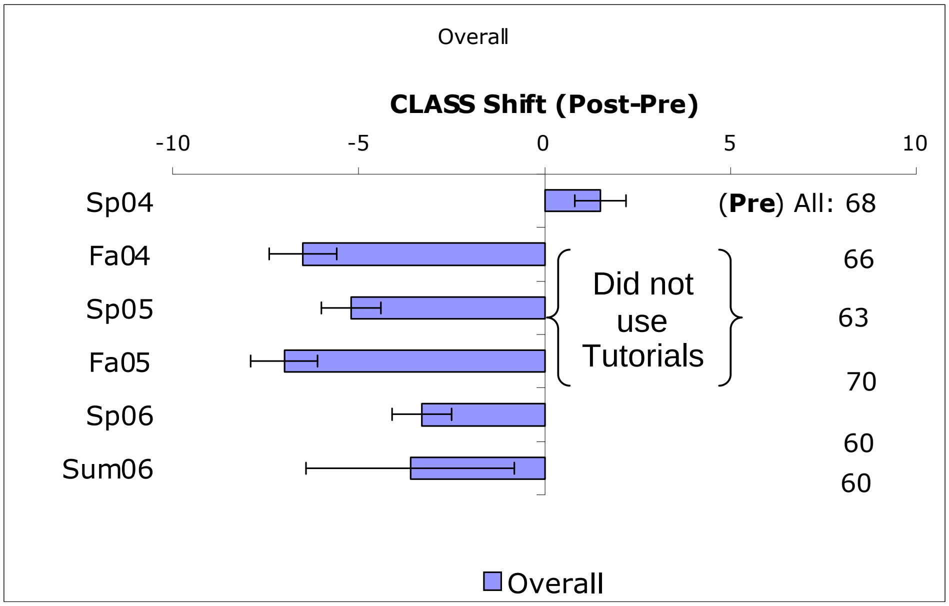

Figure 2. Comparison of CLASS shifts in several semesters.

Discussion

There are a couple of points that can be inferred from this data. First off, it cannot be said that summer semesters are parts of the school year in which learning gains cannot take place. In the data above it can be seen that the learning gains achieved in the summer 2006 semester are roughly twice the national average. Furthermore, they are comparable to the semesters in which *Tutorials* were used at CU. Also the CLASS shifts during this summer session showed small negative shifts in AB's which is also comparable to other data from CU courses in which *Tutorials* were implemented.

It is interesting that in a summer term, which generally has a pace that is roughly three times faster than that of a fall or spring semester, the learning gains and AB shifts were very comparable. After seeing such data one may question of whether or not the use of *Tutorials* and interactive engagement tells the whole story of success or failure. From this and other studies mere use of *Tutorials* and interactive engagement do not tell the whole story. There are several competing factors that influence success, and while *Tutorials* and interactive engagement do contribute tremendously to the success obtained in these transformed classrooms, it is not sufficient to say that these factors alone are responsible for success in a reformed classroom.

To pinpoint the competing factors that affect the success of these course transformations, it is useful to compare some of the conditions of implementation from what is known as a contextual constructivist perspective. This perspective uses frames of context to help identify the particular elements that impact student learning. It has been said that there are mainly four frames of context (figure 3) that impact the success of the course transformation at CU: institutional level of support, faculty beliefs and background experience, curricular tools that are used, and student background[4]. These frames are nested and generally hierarchical and influence each other, with the broader frames influencing those nested within more than the nested frames influence the broader frames. The traditional school year implementations of this course and the summer implementation of the course are compared through these frames of context.

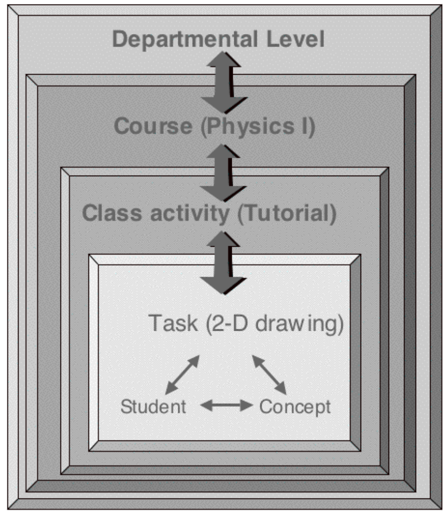

Figure 3**:** Frames of Context

Student background

During the fall and spring semesters typically first or second year students take PHYS 1110 at CU Boulder. In the summer session, however, most of the students in the class studied were upperclassmen and two were even graduate students working toward their teaching certificate. So as far as student population goes, the summer session has the upper hand because upperclassmen and graduates tend to not only be more motivated than first and second year students, but they tend to have a better grasp on study skills needed to be successful in a course, from experience. According to TA observations from the summer course the students did in fact appear to be more motivated than students she had during the traditional school year.

Curricular Tools

While fairly similar curricular tools were used in all the transformed courses, the ways in which they were used varied greatly. For example the electronic personal response systems were used in all the transformed sections. However, as described above, only two of the course sections used them in the same manner. And even then, it is not known to what extent both implementations were actually the same. Also, one of those two semesters (Sp04) was taught by a PER faculty who may have been more familiar with and had a better understanding of how the personal response systems are properly used and how best to implement them. All the other sections compared in figure 1 were taught by non-PER faculty. These different implementations may have had different affects on students' ability to gain benefit from the use of the peer instruction systems

During the traditional school year, *Tutorials* take place once per week in a very small intimate setting consisting usually of about twenty four, students one undergraduate Learning Assistant (LA) and one TA. The course meets once a week for one hour and at a homework assignment associated with the recitation lesson is usually due the next week. The LA and TA usually meet for once a week for about an hour to prepare for each tutorial.

During the summer session, *Tutorials*, ran much differently. First of all the recitations were everyday instead of once per week. This meant that a new lesson was covered each day and a *Tutorial* homework assignment was due each day. Also the size of the *Tutorial* section was different. During the summer term there were about sixty students all of whom were in the same recitation. To accommodate this size extra LA's were hired. Because of the way the room was set up, half the class had very little interaction with the TA and while this improved the student to teacher ratio, it was still a little higher than normal. The TA prepared for roughly an hour each day for the next recitation, but was only able to meet with LA's fifteen minutes before each tutorial began. The traditional school year has the upper hand in terms of instructor preparation; however frequency of meeting may have actually worked in the summer students' favor.

Faculty beliefs and background experience

Faculty beliefs and experience play a role in several aspects of a course. For example, a faculty's views on how a course should be taught are going to impact what curricular tools are used and how they are used, and in turn will ultimately impact how and what the students learn in a class. For example in the Sp05 semester, the reason peer instruction was not encouraged during the personal response questions, was because the faculty who taught the course did not believe that peer instruction is necessary to get the maximum possible benefit out of using the systems. This definitely added constraints to how the personal response systems were used as an instructional tool.

As another example, consider the instructor of the Sum06 course. At the beginning of the course he hypothesized that using the *Tutorials* would increase test performance above what he was used to seeing. To test this hypothesis he use questions from test he had given to students as another school in a traditional lecture course with no classroom reforms, and he reported that the students in the Sum06 course performed better on them. What goes on in lecture dictates the type of interaction the students will have with the recitation instructors and if the faculty does not support the reform, the recitation will not seem relevant to the student and the he/she will not get as much out of the recitation. In this case it may be that the instructor coupled *Tutorials* well with lectures.

Institutional Level of Support

Institutional support is the broadest of all these frames of context. It has the most impact on all other frames (as they are all nested inside it). At the institutional level the it would appear that fall or spring courses would have the upper hand over summer courses. by far for several reasons. First off the course is longer. This allows for a slower pace, and more spaced out classes and allows the instructor the flexibility to spend more time on certain topics if need be. This could have quite a bit of impact on the student's knowledge gain throughout the course of the semester. Also, there is less material covered in each lecture and the frequency of lectures is much lower in the fall/spring semester. This structure allows the student to process the material a little bit at a time. This time also makes it easier for student and instructor to identify misconceptions and trouble spots and to adapt. Also the pace could have affected the instructor's ability to go over examples.

On the other hand however these effects could have been mitigated by the fact that during the traditional most students typically take five or more classes. Summer students; however usually only take one course, maybe two. In this case the workload and pace of the summer structure could be somewhat canceled out by the increased course load of the traditional school year.

Conclusions

It has been seen from this study that when classroom transformations are implemented in a summer setting it is possible to obtain similar learning gains to those achieved in a transformed classroom during the school year. It is also seen here that while similar PER-based reforms were implemented, their implementation was quite different. Several competing factors may be attributed to these outcomes. The frames of context perspective appears to identify many of these factors, which may also have an effect on outcomes not accounted for in a given set of frames of context.

The results of this study were surprising considering some of the constraints on the course, however they have shown success at about the level of that of a transformed course taught over a longer period of time. Several things would be interest to investigate further. First of all, it is interesting whether or not these results are repeatable. Also the question of whether any one particular factor contributed most to the result achieved in this study. Finally, what happens in a summer course which is not reformed?

[1] L.C. McDermott and E.F. Redish, Am. J. Phys 6, 755 (1999).
[2] E.F. Redish, *Teaching Physics with The Physics Suite* (Wiley, New York, 2003)
[3] Pollock, S., "*Transferring Transformations…*", PERC Proceedings 2005, Salt Lake City, UT.
[4] Finkelstein, N., and Pollock, S., "*Sustaining Change…*", PERC Proceedings 2006, Syracuse, NY.
[5] Finkelstein, N. and Pollock, S., "*Replicating & Understanding Successful Innovations*", Phys. Rev ST Phys. Educ. Res. 1, 010101 ('05).