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ABSTRACT

This paper describes major changes undertaken in two undergraduate physics courses from traditional lecture method to an inquiry-based method that facilitates active student engagement and changes in the modeling approach to learning. Students' conceptual understanding of physics concepts were evaluated by quasi-experimental design, and the Reform Teaching Observation Protocol (RTOP) was used to evaluate instructors for reformed teaching practice. (Contains 27 references.) (YDS)

Effect of Reformed Courses in Physics and Physical Science on Student Conceptual Understanding

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Introduction

The use of active-engagement methods in teaching physics has been shown by Hake (1998) to significantly improve students' conceptual understanding of calculus and algebra based physics. The present paper extends Hake's (1998) methods of analysis to PHY 121, a calculus based physics course undergoing major changes in it modeling approach to learning, and to PHS 110, a large enrollment inquiry-based general studies physical science class open to all students, and taken by pre-service elementary education students. Here we report changes in students' conceptual understanding of fundamental concepts in these introductory courses at Arizona State University (ASU) and several Maricopa Community Colleges in the Greater Phoenix area.

During the past twenty years, science education researchers have been studying students' conceptual understanding of science. This research indicates that at all levels of instruction students are not learning what teachers think they are teaching. This discrepancy seems to be due to a mismatch of how the teacher teaches versus how the students learn (McDermott, 1993, Driver, 1989; Tobin, Tippins, & Gallard, 1994; von Glasersfeld, 1987, 1989). Teaching by lecturing with students passively taking notes is very ineffective. Instead, a much more effective way to learn is for students to be actively involved in thinking and discussing during both class and laboratory, with the goal of having the students develop a deep understanding of scientific concepts. This goal is in accord with the educational practices advocated by the major professional science education communities (American Association for the Advancement of Science [AAAS] 1989, 1993; National Research Council [NRC] of the National Academy of Sciences, 1996).

This report is divided into two parts. Part One reports the studies done to assess the reforms in PHS 110; Part Two reports the studies done to assess the reforms in PHY 121.

Part One – PHS 110

The ASU PHS110 class was reformed by Dr. Susan Wyckoff as part of the Arizona Collaborative for the Excellence in the Preparation of Teachers (ACEPT), a program funded by the National Science Foundation to reform key science and mathematics courses and curricula taken by students intending to become K-12 teachers. Dr. Wyckoff began with the conception that a reformed classroom was one where students are interactively engaged as members of a learning community. In her view, students in a reformed class analyze evidence, reflect upon their learning, make observations and make predictions. There is active participation by the students with a variety of levels and paths for their investigations.

Reforming a Large Enrollment Physical Science Course

Prior to the ACEPT program, the ASU Physical Science (PHS110) course was taught using traditional lecture methods, and the entire class (typically 80-100 students) met three times a week in a large lecture room. Breakout laboratory sections associated with the course were scheduled at various two-hour time slots throughout the entire week.

In fall of 1996 the major reforms introduced in the ASU PHS110 course included: 1) closely coordinating the lecture with the laboratory activities, 2) scheduling all laboratory sections to meet between the Monday and Wednesday lecture times, 3) converting both lecture and laboratories to a learning cycle model of pedagogy, 4) introducing take-home laboratories as homework, and 5) implementing ClassTalk technology (Dufresne et al. 1996) to facilitate active engagement in the lectures.

With the reformed schedule for PHS110 students explored one or more new concepts on Tuesday of each week in small break-out laboratory sections (usually 10-15 students) before the concepts were discussed in the large class forum which continued to meet on Monday, Wednesday and Friday in the large lecture hall. The laboratories were open-ended and discovery-based, with the laboratory instructors (graduate teaching assistants) using Socratic-type questioning. The initial Tuesday laboratory explorations provided the basis for the large group interactions in the Wednesday lecture when new terms were introduced.

ClassTalk is an electronic feedback system developed by Better Education which promotes group and all-class discourse in large enrollment environments. Each group of 3-4 students is equipped with a Texas Instruments, TI-85 calculator which is linked to with a Macintosh computer controlled by the Instructor. Multiple-choice conceptual questions can be displayed on the screen at the front of the classroom. The student groups then engage in discussion of the problem for several minutes, and each student sends his/her answer via the group's TI-85 calculator to the Macintosh which compares the answers submitted with the correct choice, performs the class' statistics for that problem, and displays a histogram of the numbers of answers the class gave for each answer choice. Thus the students immediately (within about 30 seconds) receive anonymous feedback on the correctness of their reasoning. At the same time the instructor receives an overview of the class' understanding of the concept addressed in the question. With the aid of ClassTalk the instructor can quickly change back and forth between student-centered groups engaging in discourse to a full-class discussion, and the technology is also a very effective classroom management tool for controlling discussions. Thus ClassTalk provides an effective and efficient means of transforming the classroom discourse into an active, open-ended inquiry session. The students are challenged by ClassTalk to generate solutions cooperatively, articulate their reasoning and defend their choices. Through discourse students' understanding of relationships and models can be clarified and formalized. On Fridays and Mondays ClassTalk was used to review, consolidate and evaluate students' understanding of the one or two concepts introduced that week (in the Tuesday laboratories). The home-based (take-home) laboratory assignments extend scientific inquiry to the home environment where family members can participate with the student in simple experiments involving everyday phenomenon and inexpensive materials.

Instrumentation

To evaluate students' conceptual understanding of physics concepts covered in the class, a traditional pretest-posttest quasi experimental design with control groups was employed. An instrument, the Physics Concept Survey (PCS), was developed to measure students' learning by one of the authors (SW), and includes the most fundamental concepts in introductory physics. Also the instructors of the course were evaluated for reform teaching practice using an instrument called the "Reformed Teaching Observation Protocol" (RTOP). The RTOP was developed to measure the degree to which the teaching was in accord with the ACEPT program criteria for reformed teaching. The RTOP does not purport to measure whether the instruction was good, only if the instruction was reformed.

Physics Concept Survey (PCS)

Conceptual understanding of mechanics was measured using a fourteen item, multiple-choice test, which is the mechanics sub-test (MPCS) of the PCS. The 30 items in the PCS were designed to measure students' conceptual understanding of one-dimensional Newtonian mechanics, momentum, gravitational force, energy, electricity and magnetism, and basic properties of light. Many of the mechanics items are based directly on the Force Concept Inventory (FCI) (Halloun &Hestenes, 1986; Hestenes et. al. 1992a, 1992b). Other items were taken from Peer Instruction (Mazur 1996) and from Conceptual Physics (Hewitt 1999). The PCS was tested in the ASU PHS110 classes during the fall 1996 and spring 1997 spring semesters, after which an item analysis was performed on the original test. Several PCS items with reverse discrimination indices were revised, and the new version of the PCS was re-administered to the PHS110 classes in fall 1997 through spring 1999 semesters at ASU. An item analysis of the PCS after revision produced KR20 reliability coefficients that ranged from 0.62 to 0.87 for the entire test and the sub-tests. The item analysis of just the MPCS gave a KR20 reliability coefficient of 0.80. The MPCS and PCS are administered via paper. The PCS is currently being prepared for publication.

Reformed Teaching Observation Protocol (RTOP)

The Reformed Teaching Observation Protocol (RTOP) (Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., & Judson, E. 2000) was developed as an observation instrument to provide a standardized means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed. The developers, ACEPT's Evaluation Facilitation Group (EFG), did not presume that reformed instruction is necessarily quality instruction. Rather we left that as an hypothesis to be examined and tested in and across various reformed settings. The RTOP draws upon the principles of reform and the work underlying the ACEPT project including the "standards" in science and mathematics education [NCTM's Curriculum and Evaluation Standards (1989), Professional Teaching Standards (1991), Assessment Standards (1995) and NRC's National Science Standards (1996)]. RTOP consist of five sub-scales with a maximum of 20 points for each sub-scale for an overall total of 100. Despite the fact that each sub-scale is based on just five items, reliabilities are still very respectable as shown in Table 1. The reliability of the total score is 0.954.

Table 1

Reliability Estimates of RTOP Sub-scales and Total Score

Name of Sub-scale	R-Squared
Sub-scale 1: Lesson Design and Implementation	0.915
Sub-scale 2: Content – Propositional Pedagogic Knowledge	0.670
Sub-scale 3: Content – Procedural Pedagogic Knowledge	0.946
Sub-scale 4: Classroom Culture – Communicative Interactions	0.907
Sub-scale 5: Classroom Culture – Student/Teacher Relationships	0.872
Total Score	0.954

Data Collection

The data on the control and experimental groups were collected in fall 1998 (1 control, 1 experimental), spring 1999 (1 control, 1 experimental) and fall 1999 (1 control, 1 experimental) semesters. The intervention was the ACEPT reform manner of teaching in the PHS110 classes (experimental group). The control groups were selected introductory ASU physics classes and a community college class whose instructors had not been exposed to current reform teaching methods. The MPCS instrument was administered as a pretest-posttest for both the control and experimental courses.

Fall 1998 Term

In August 1998 an introductory physics course for pre-engineering students who had never taken physics previously was used as the control class. A very traditional lecturer taught the class; little or no student activity occurred in the class, and the laboratory was not related to lecture material. This course only covered mechanics, which was not apparent from the initial discussion with the professor about course content. However, because the professor of the control group did not want his students to be tested on material not covered in his class, the control group took only the MPCS as a posttest. The students in the experimental PHS 110 class took the entire 30-item test as a posttest. Both classes took the PCS as a pre-test.

Spring 1999 Term

In January 1999 the control class was a standard college conceptual physics class taken by non-science majors for laboratory science, liberal studies, credit. The professor teaching the course was considered a very good teacher and had won several teaching awards. Although this control course covered content similar to PHS 110, the professor of the control group decided that some of the material on the PCS was not adequately covered in his class. Therefore the control group took the MPCS as a posttest. The students in the experimental PHS 110 class wrote the entire 30-item PCS test as a posttest.

Fall 1999 Term

In August 1999 the control class was PHS 110 taught at a community college. The professor teaching the course was considered to be very good teacher. The control course covered most of the content of ASU's PHS 110, with the addition of chemistry. The students in the control class wrote the entire 30-item PCS test as a pretest-posttest. The students in the experimental PHS 110 class took the entire 30-item PCS test as a pretest-posttest.

Attrition Problems

The achievement data were analyzed using matched pairs for the pretests and posttests. Matched pairs were initially used because of attrition in the fall 1998 control group. The fall 1998 control group started with 58 students in two sections. By the end of the semester, there were only 16 to 20 students regularly attending the control class. Use of matched pairs assured that the same students took both the pretest and posttest. Attrition was not a factor in the other classes. The fall 1998 PHS 110 started with 67 students in one section. By the end of the semester, 50-58 students were regularly attending PHS 110 class. The numbers were similar for the spring and fall 1999 semester, PHS 110, class. The spring 1999 control class had 250 students in two sections. There were 70-100 students attending each class at the end of the semester. The fall 1999 control class had 23students attending out of 25 attending at the end of the semester.

RTOP

In all three terms, all classes were observed at least two times to gather RTOP data. A pair of observers usually did the observations, one trained in mathematics, the other in Physics.

Data Analysis

Data were collected from three experimental classes and three control classes over three instructional terms. Each class was administered a content pretest and posttest. As well, each class was observed two or more times to collected RTOP scores. A pretest mean, a posttest mean, and an RTOP mean were calculated for each class. The significance for the pre-test and post-test scores per class and gains were calculated using a student t-test. The analysis was organized by term.

Results

RTOP Profiles

Before examining the results of the quasi-experimental comparisons it is important to establish that, even though many reforms were implemented in PHS 110, did these enactments actually result in classrooms, which were reformed? The Reformed Teaching Observation Protocol (RTOP) was used to observe the teaching all of the sections of PHS 110 resulting in RTOP scores ranging between 66-79 for the experimental classes and scores ranging from 16-43 for the control classes. As summarized in Table 2, all RTOP sub-scales revealed significant differences between the experimental and control groups at the 0.01 level of significance. Only on Sub-scale 2 do you see scores that are close. This makes sense since Sub-scale 2 focuses on "content" whereas the other scales focus on lesson design, classroom procedures, communicative interactions, and teacher-student relationships. These results suggest that the lessons of the control instructors are strongly coherent with respect to content but are lacking in the other dimensions of reform. Figure 1 summarizes the RTOP comparisons in graphic form.

Table 2

Differences Between Means on the Sub-scales of RTOP
For PHS 110 and Control Groups

Variable	PHS 110 Means (n = 6)	Control Means (n = 6)	Difference	Significance of the Difference
Sub-scale 1	13.17	4.5	8.67	$P < 0.01$
Sub-scale 2	17	14.17	2.83	$P < 0.01$
Sub-scale 3	14	2.5	11.5	$P < 0.01$
Sub-scale 4	15.33	5.5	9.83	$P < 0.01$
Sub-scale 5	13.83	5.5	8.33	$P < 0.01$
Total Score	73.33	32.17	41.17	$P < 0.01$

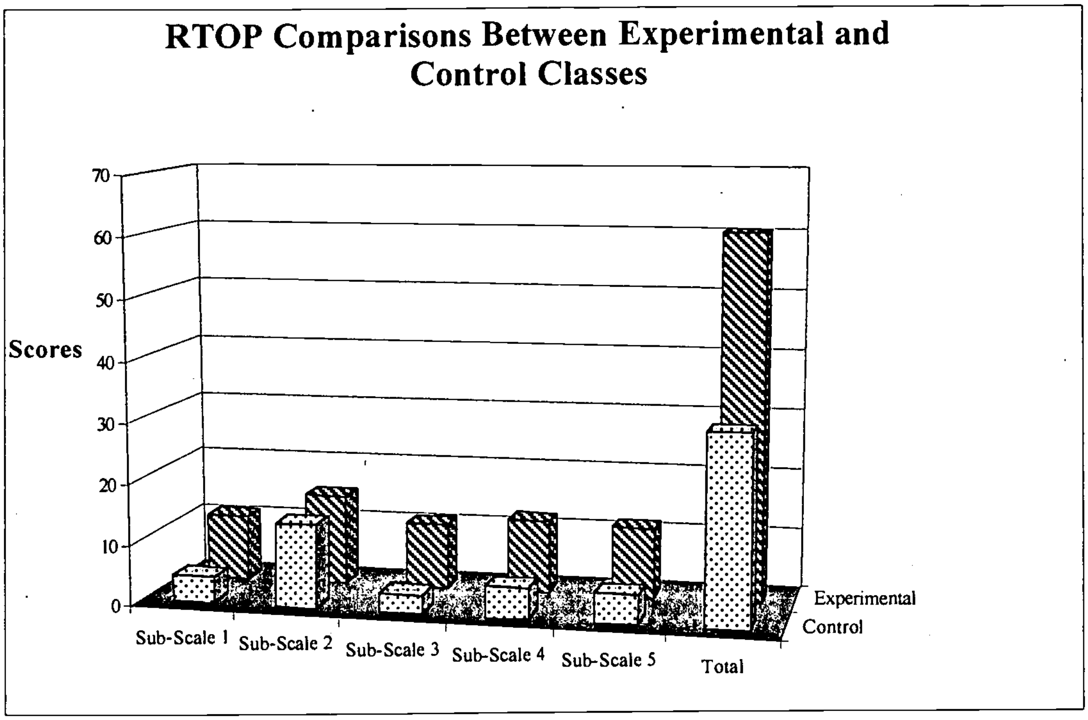


Figure 1. RTOP Comparisons between PHS 110 and control classes

The RTOP analysis verifies that the PHS 110 classes are substantially reformed. The question of whether such reforms make a difference in terms of conceptual gains is answered in the next section.

Conceptual Gains

For the Fall 1998 and Spring 1999, the control classes scored significantly higher than the experimental classes on the MPCS pretests, however the PHS 110 students performed significantly better than the control group on the MPCS posttests. Thus even though the reform PHS 110 class started with lower initial average MPCS scores, the average MPCS posttest scores were significantly higher than the control groups. These differences on the posttest are particularly interesting because control fall 1998 and control spring 1999 spent more time in the semester working on mechanics than did the experimental. In fact, the fall 1998 control spent the entire semester working on mechanics. Even though these controls had spent more time, their posttest scores were less than, the PHS 110 students who spent approximately five weeks on mechanics.

For the fall 1999, the control class scored higher the experimental class on the MPCS pretests, but not statically significantly higher. However, again on the posttest, the PHS 110 class had an average MPCS posttest scores which were significantly higher than the control group.

Table 3
Means and Standard Deviations of the Experimental and Control Groups on MPSC

	Fall 98				Spring 98				Fall 99			
	Experimental		Control		Experimental		Control		Experimental		Control	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
*Pre	5.1	2.3	7.0	3.4	5.3	2.3	6.1	2.2	4.7	2.5	6.2	2.1
*Post	9.1	2.5	7.6	2.7	9.5	2.7	7.8	2.3	9.8	2.2	7.9	2.4

*Maximum Score is 14

The gain score we are using is the Hake gain from R. Hake (1998). For given set of students it is defined formulaically as (mean posttest score -mean pretest score)/ (maximum test score - mean pretest score). The Hake gain or Hake Factor is usually associated with the Force Concept Inventory (FCI) (Hestenes, Wells & Swackhamer, 1992) The Hake gain attempts to adjust for differing initial student competence. The experimental classes demonstrated Hake gains at least twice those of the control groups over the three semesters studied. The difference in Hake gains between the experimental and the control courses is statistically significant (p<0.01).

Table 4
Hake Gains of Experimental and Control Groups on MPSC

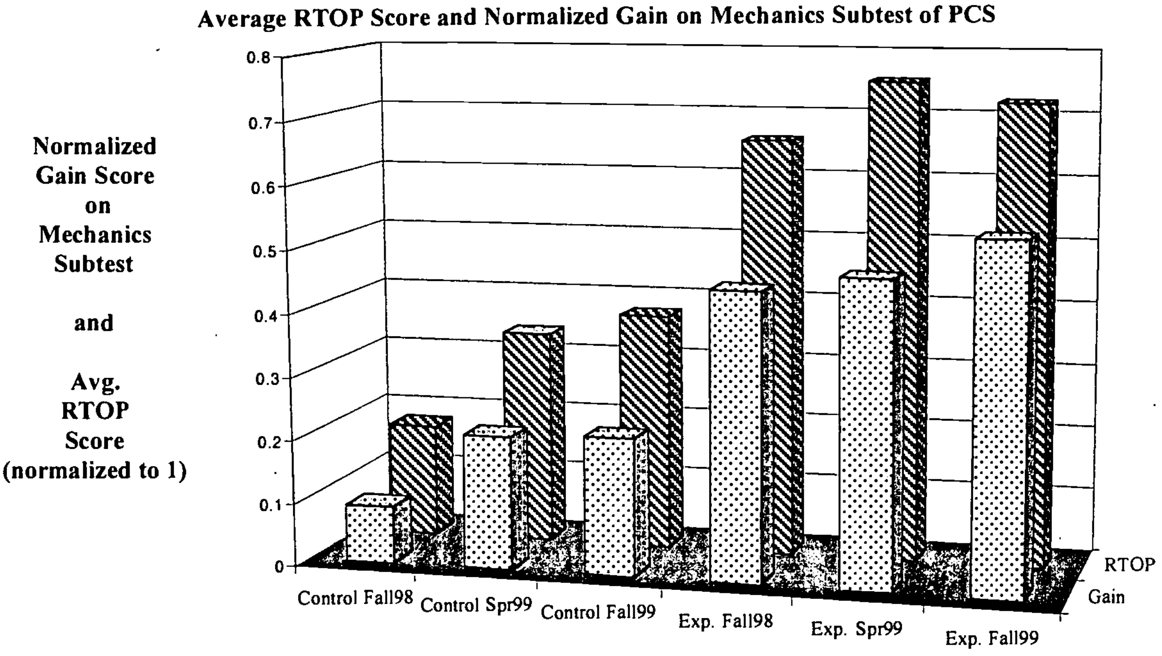
	Fall 98		Spring 98		Fall 99	
	Experimental	Control	Experimental	Control	Experimental	Control
	H	H	H	H	H	H
Hake Gain* [1]	0.45	0.09	0.48	0.21	0.54	0.22

* Hake Gain is a normalized gain. Calculated for a class by (avg. post score-avg. pre score)/(max. score possible - avg. pre score)

[1] The Hake Gain for the Experimental Groups was significantly greater than the Hake Gain for the Control Groups. (p<0.01)

Relationship between RTOP and Conceptual Gains

The control groups normalized gains were significantly lower than the experimental groups (p<0.01), on the MPCSs. The RTOP scores for the control instructors ranged from 16 to 43. All of the control classes had average RTOP scores less than 40. For the experimental classes at ASU, the two instructors had similar average RTOP scores with the same instructor having taught both fall semesters. The RTOP scores ranged from 66 to 79, which indicated good reform practice in the courses. The correlation coefficient between RTOP and the normalized gain on the MPCS was 0.98. This would indicate that reform teaching, interactive inquiry-oriented instruction, results in greater student conceptual instruction, results in greater student conceptual



The correlation coefficient between RTOP and normalized gain on the mechanics subtest of PCS is 0.98.

Figure 2. Average RTOP Score and Normalized Gain (Hake Gain) on the Mechanics Subtlest of the Physics Concepts Survey for Experimental and Control classes Fall 1998-Fall1999

Summary and Conclusions

We conclude that students in the ACEPT reformed PHS110 course learned significantly more physics concepts, than students in the traditional lecture classes (control groups). Our work therefore extends that of Hake (1998) from science students in interactive engagement physics classes to physics classes for non-science students. The significance of our investigation is that non-science students demonstrate significantly greater learning of fundamental physics concepts in active-engagement classroom environments compared with traditional lecture classes. Furthermore, our data show that significant learning can take place in large-enrollment classrooms managed by efficient electronic feedback systems such as ClassTalk. Our results have important bearings on effective teaching of undergraduate general studies laboratory physics courses taken by pre-service elementary education students. Clearly, a well-designed physics or physical science course for elementary education students which incorporates results from studies such as found here has the potential of significantly improving elementary teachers' understanding of physics concepts, and therefore their abilities to teach the subject well.

Our work addresses a possible concern with Hake (1998) the wide spread in the normalized gains for the Interactive Engagement courses. Hake indicated there was "the presence of implementation problems."(70 Hake 1998) However, the level of interactive engagement (reform) was entirely self reported. The RTOP as a measure of reform, removes the self-reporting form the level of reform. The high correlation with the RTOP and normalized gains would support Hake's hypothesis of implementation problems.

Part TWO – PHY 121

The Modeling Method is both a philosophy of teaching and a curriculum for physics education. David Hestenes developed the philosophy. In 1983, David Hestenes had drafted a paper on physics pedagogy using the ideas of scientific models for teachers to use to teach physics. The curriculum part of the Modeling Method was originally developed and enacted by a high school physics teacher, Malcolm Wells, with Prof. David Hestenes (Hestenes, Wells & Swackhammer, 1995) The Modeling Method was developed to correct what Hestenes, and others saw as weaknesses of the traditional lecture-demonstration method. These weakness were quantified by two multiple choice, conceptual assessments of student's mechanics understanding, The Mechanics Baseline Test (Hestenes & Wells,1992) and The Force Concept Inventory (Hestenes, Wells & Swackhamer,1992). The National Science Foundation supplied funding for the development of assessments and workshops for high school teachers. The high school teachers in the second year of the workshop helped to modify and expand the curriculum. It is this expanded and modified curriculum, which is referred to as the Modeling Method and can be found at <http://modeling.la.asu.edu> as well as the educational research program directed by Prof. David Hestenes (Hestenes, 1997).

Modeling Method - Curriculum and Philosophy

The Modeling Method seeks to address perceived weaknesses of the traditional lecture-demonstration method including the fragmentation of knowledge, student passivity, and the persistence of naive beliefs about the physical world. In modeling the students are engaged in understanding the physical world by constructing and using scientific models to describe, to explain, to predict and to control physical phenomena. Having the students learn and use a variety of conceptual tools, including Microcomputer Based Laboratories (MBLs), Calculator Based Laboratories (CBLs), white boards, etc facilitates student understanding. Students use these tools along with a small set of basic models to develop insight into the structure of scientific knowledge by examining how models fit into theories. The students evaluate the scientific models through comparison to empirical data they have collected. For example, students start out in mechanics by modeling an object as a single particle, but the single particle model breaks down when you have to take into account internal energy. The students realize the single particle model doesn't work by collecting and analyzing data from a bouncing ball. Then the extended body model is introduced. The students are forced to make predictions and confront their naive beliefs about the physical world.

The Modeling Method of instruction is organized into modeling cycles: model development, evaluation and application. The teacher sets the stage for student activities, typically with a demonstration and class discussion to establish common understanding of a question to be asked of nature. Then, in small groups, students collaborate in planning and conducting experiments to answer or clarify the question. After the students have conducted the experiments, they are required to present and justify their conclusions in oral and/or written form to the group. Particular attention is paid to the formulation of models for the phenomena in question and evaluation of the models by comparison with data. Only after the students have experienced the phenomena and have grappled with the concepts, does the teacher introduce technical terms and concepts. The Modeling curriculum has a definite agenda for student progress and a taxonomy of typical student misconceptions. These help facilitate the teacher's guidance of student inquiry and discussion as students are induced to articulate, analyze and justify their personal beliefs. The teachers use "Socratic" questioning and remarks to address the students' naive conceptions. The Modeling Method of instruction promotes an integrated understanding of the process of developing, constructing and assessing scientific models.

Discourse Practice: Re-Modeling University Physics

The modeling approach at Arizona State University has undergone subtle yet major transformation in the past three years as embodied for example in the ReModeling Summer Workshop 1999. Led by Dwain Desbien, a doctoral student whose own teaching had generated the highest Hake gains to date, the intent of the workshop was to help participants experience and understand how critically important the formation of discourse communities was in the modeling classroom. In bringing the workshop participants into a inquiry-community in its own right, the workshop leader enabled them to appreciate how students could be guided to constitute inquiry communities participating in interactive communication that not only led to the critique and creation of basic models of physics but in doing so made the community they constituted aware if its own practice (see Sawada, 1999 for more detail).

The workshop had major impact on most of its participants and set the conditions for assessing the remodeling research reported here. Some of the participants in the summer workshop were scheduled to be instructors for PHY 121in the fall term making it possible to set up a quasi-experimental design for assessing the effects of the new discourse-oriented approach to modeling.

Instrumentation

To evaluate students' conceptual understanding of physics concepts covered in the classes, a traditional pretest-posttest quasi experimental design with control groups was employed. The Force Concept Inventory (FCI) was used. The FCI was originally developed to measure conceptual gains in mechanics for Modeling Method instruction, but is now used by many Physics educators to measure conceptual gains in student understanding (Hake, 1998). The instructors of the courses were evaluated for reform teaching practice using an instrument called the "Reformed Teaching Observation Protocol" (RTOP). Since the Modeling Method had become associated with ACEPT, Modeling Method was assumed to meet the ACEPT program criteria for reformed teaching.

Force Concept Inventory (FCI)

Conceptual understanding of mechanics was measured using a thirty item, multiple-choice test. The 30 items in the FCI were designed to measure students' conceptual understanding of Newtonian mechanics and forces. (Halloun &Hestenes, 1985; Hestenes et. al. 1992a, 1992b). A critic of the FCI was published by Heller where she refutes some of Halloun & Hestenes claims but the FCI is still the standard test used by Physics Education Research (PER) in mechanics.

Reformed Teaching Observation Protocol (RTOP)

The Reformed Teaching Observation Protocol (RTOP) (Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., & Judson, E. 2000) was developed as an observation instrument to provide a standardized means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed. Please see a fuller description in Part I.

Data Collection

In order to assess whether the remodeled approach could lead to high achievement in PHY 121, introductory mechanics with calculus; a pretest-posttest quasi experimental design was arranged. The data on the control and experimental groups were collected in fall 1999 (with 3 experimental classes and one control class). There were originally two control classes, but the instructor of the second control class after an initial acceptance, refused to allow the post test administration of the FCI. The intervention was the Modeling Method of reform teaching in the PHY 121 classes (experimental group). The control groups were the other two ASU PHY 121 classes whose instructors had not been exposed to current reform teaching methods. The FCI instrument was administered as a pretest-posttest for both the control and experimental courses.

Fall 1999 Term

- Experimental Class 1: A PHY 121 course offered at a Maricopa Community College taught by the leader of the Modeling Summer Workshop..
- Experimental Class 2: A PHY 121 course offered in "studio" mode as part an integrated approach to preparing engineers taught by an instructional team consisting of the leader of the Modeling Summer Workshop, a Professor of Physics and a graduate student both of whom had attended the Summer Workshop.
- Experimental Class 3: An "honors" section of PHY 121 at ASU taught by a co-teaching colleague of Dwain Desbien. The two Teaching Assistants had attended the Modeling Summer Workshop.
- Control Class: A "regular" large lecture section of PHY 121 at ASU. The instructor had not attended the Modeling Summer Workshop.

Attrition Problems

The achievement data were analyzed using matched pairs for the pretests and posttests. The pre-test and posttest means were calculated for each class, except for the second control class which did not participate. There was no statically significant difference between the pre-tests means for the two control classes.

RTOP

All classes were observed at least two times to gather RTOP data. The RTOP instrument was administered a minimum of 3 and a maximum of 7 times by a pair of observers, one trained in mathematics, the other in Physics.

Data Analysis

Data were collected from three experimental classes and one control classes over the instructional term. Each class was administered a content pretest and posttest. As well, each class was observed two or more times to collected RTOP scores. A pretest mean, a posttest mean, and an RTOP mean were calculated for each class.

Results

RTOP Profiles

Before examining the results of the quasi-experimental comparisons it is important to establish that, even though many reforms were implemented in PHY 121, did these enactments actually result in classrooms, which were reformed? The Reformed Teaching Observation Protocol (RTOP) was used to observe the teaching all of the experimental classes of PHY 121 resulting in RTOP scores ranging between 78-99 for the experimental classes and scores ranging from 17-39 for the control classes. The second control group was included in the sub-scale analysis since the question was are these classes reform, per our definition via RTOP. As summarized in Figure 3, all RTOP sub-scales revealed significant differences between the experimental and control groups at the 0.01 level of significance. Only on Sub-scale 2 do you see scores, which are close. This makes sense since Sub-scale 2 focuses on "content" whereas the other scales focus on lesson design, pedagogy, discourse and teacher-student relationships. These results suggest that the lessons of the control instructors are strongly coherent with respect to content but are lacking in the other dimensions of reform. . A total of 19 RTOP observations were made by two different observers of the four classes participating in the study. As shown in Table 5, the mean RTOP for the experimental classes are all substantially higher than the mean for the control class ($p < .01$).

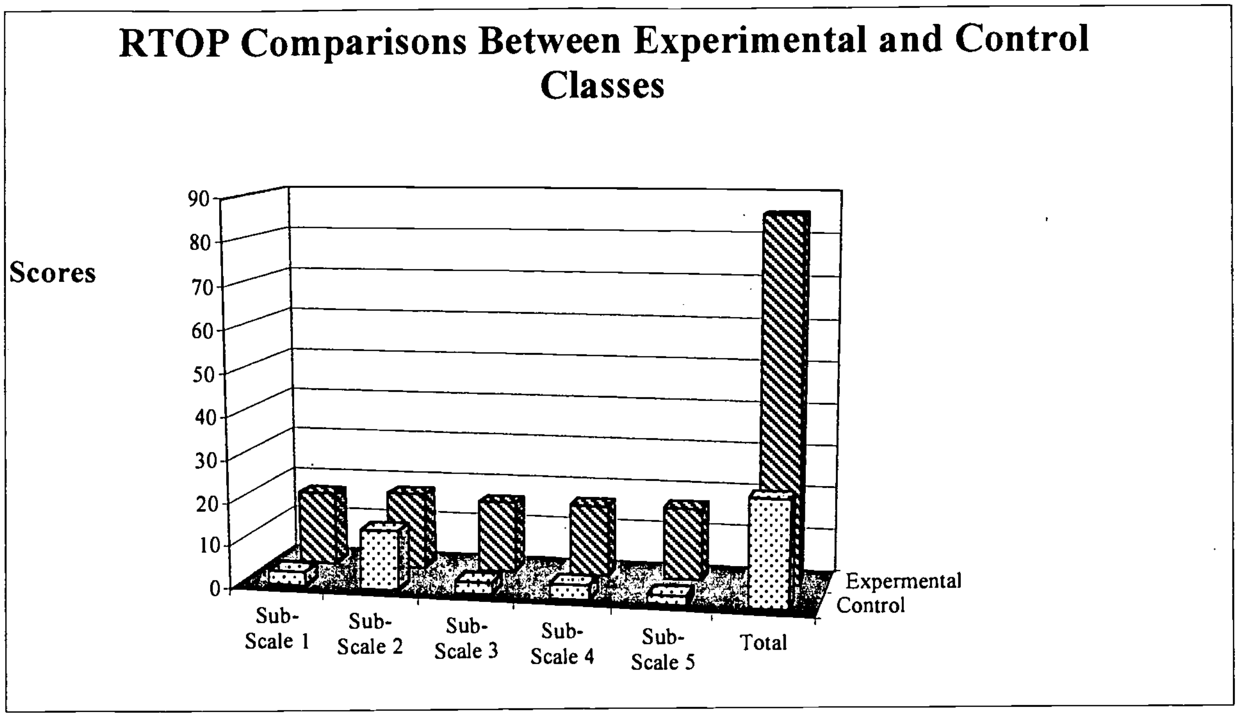


Figure 3. RTOP Comparisons between PHY 121 and control classes

Table 5

RTOP Mean Scores for Each Class

Class	No. of RTOP Administrations	Mean RTOP Score
Experimental 1	3	98.5
Experimental 2	7	79.7
Experimental 3	4	85.7
Control	5	27.2

Conceptual Gains

The Force Concept Inventory (FCI) was administered early in the semester as a pretest and again toward the end of the semester as a posttest. As shown in Table 6, the difference between the mean pre-test and post-test scores for Experimental class 3 is only marginally higher than the gain for the Control class (5.6 vs. 5.0). This unexpected outcome could be due to the presence of a 'ceiling" effect: Experimental 3 is an honors class which had a pretest mean that is much higher than the control pretest mean. The Normalized Gain score is precisely the kind of score, which attenuates for ceiling effects. As shown in Table 6, when Normalized Gain scores are considered, Experimental 3 scored higher (0.51) than the control class (0.32). Indeed, the Normalized Gain score for each of the experimental groups was significantly higher than the Normalized Gain for the control class ($p < .01$).

Table 6

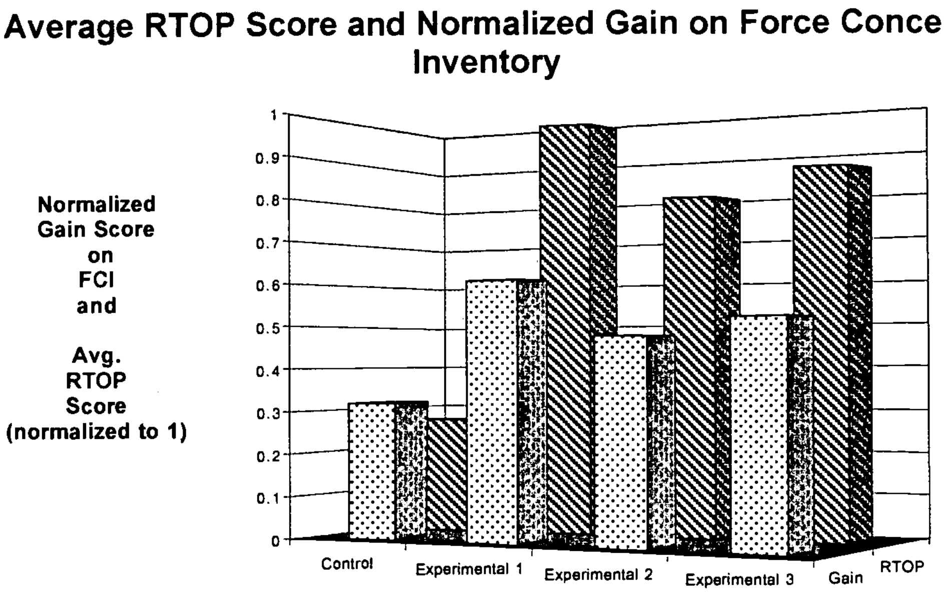
Pretest – Posttest Comparisons of Experimental and Control Classes on the FCI

FCI	Experimental 1	Experimental 2	Experimental 3	Control
Pretest Mean	13.9	13.7	19.1	14.3
Posttest Mean	23.6	21.3	24.7	19.3
Hake Gain*	0.60	0.47	0.51	0.32

* Normalized Gain = Gain / (Max score – Pretest mean). Referred to as the "Hake" factor

Relationship between RTOP and Conceptual Gains

The control group's normalized gain was significantly lower than the experimental groups ($p<0.01$), on the FCI. The RTOP scores for the control instructor was a mean of 27.2. For the experimental classes, the RTOP scores ranged from 77 to 99 that indicated good reform practice in the courses. The mean RTOP scores were 98.5, 79.7 and 85.7. The correlation coefficient between RTOP and the normalized gain on the FCI was 0.97. This would indicate that reform teaching,, interactive inquiry-oriented instruction, results in greater student conceptual understanding.



The correlation coefficient between RTOP and normalized gain on the FCI is 0.97.

Figure 4. Normalized Gain on the Force Concept Inventory v.s RTOP for Experimental and Control Classes.

Conclusion

The results indicate that the remodeling method as used in the three experimental classes outperformed the control class on the Force Concept Inventory. Furthermore, the three experimental classes are much more reformed than the control class as indicated by data on the Reformed Teaching Observation Protocol.

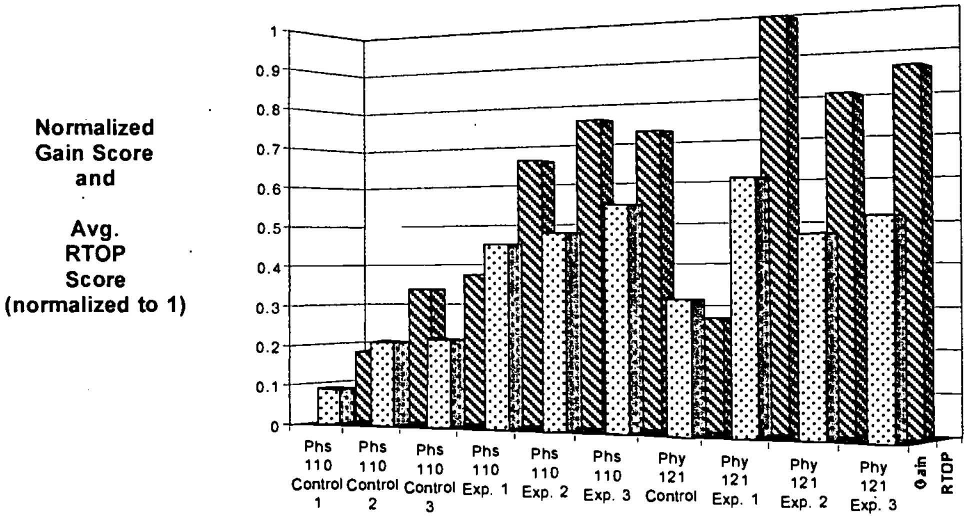
Hake used the term interactive engagement to mean something very similar to our version of reform. The gain scores when compared to Hake's histogram of the average normalized gain, would indicate the experimental gain scores were comparable to the middle to high range of gains for interactive engagement. Interestingly, the control gain of 0.32 was the highest of the reported traditional classes. (Hake, 66,1998). However, Hake makes the claim that several of the lower normalized gain scores should not be considered as interactive engagement because the implementation was not correct. Hake made these comments based on others understanding of the classrooms as not being interactive engagement when they had self-reported as interactive engagement. This is the advantage of using an instrument for classroom observations like the RTOP, which could have been used to measure the difference in reform in the classrooms and helped answer whether or not interactive engagement works in the physics classroom.

Reflection on Part One and Two

The results shown in Part One and Part Two of this paper reveal significant achievement gains in favor of the experimental classes for both physics and physical science courses. It is safe to conclude that the reforms embodied in PHY 121 and PHS 110 result in both greater gains in student achievement (FCI) and higher scores on classroom reform (RTOP). The quasi-experimental designs offer support for the claim that the greater achievement gains are attributable to the reformed nature of the instruction in the experimental groups. However, it must be admitted that quasi-experimental designs do have many threats to validity not the least of which is the non-randomness of assignment of subjects to treatments. For these and other reasons, we do not claim that reformed instruction causes higher achievement gains.

However, the following correlation data offer a striking portrayal of the relationship between reformed teaching and achievement gains. Because Normalized Gain scores are a pure number, the data from PHY 121 and PHS 110 can be combined. The RTOP score and the Normalized Gain score for each of these ten classes is shown in Figure 5. The relationship between degree of reform and amount of normalized gain is striking: the two measures appear to rise and fall in lock-step fashion.

Average RTOP Score and Normalized Gain for Phs 110 and PHY 121



The correlation coefficient between RTOP and normalized gain is 0.94.

Figure 5. The Relationship Between Degree of Reformed Teaching and Student Learning

The correlation between RTOP and Normalized Gain for the 10 data points shown in Figure 5 is 0.94. Although the sample size is small a correlation of this magnitude is significant at the .01 level.

We conclude that a very strong relationship exists between reformed teaching and student learning.

References

American Association for the Advancement of Science (1989). Science for all Americans. New York: Oxford University Press.

American Association for the Advancement of Science (1993). Benchmarks for Science Literacy. New York: Oxford University Press.

Brickhouse, N. W. (1989). The teaching of philosophy of science in secondary classrooms: Case studies of teachers' personal theories. International Journal of Science Education, 11(4), 437-449.

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. Journal of Teacher Education, 41(3), 53-62.

Driver (1989). The construction of scientific knowledge in school classrooms. In R. Miller (Ed.) Doing science: Images of science in science education. London: Falmer Press.

Dufresne, R.J., Gerace, W.J., Leonard, W.J., Mestre, J.P. & Wenk, L. (1996) ClassTalk: A classroom communication system for active learning. Journal of Computing in Higher Education, 7, 3-47.

Halloun, I.A. & Hestenes, D. (1985) The initial knowledge state of college physics students. American Journal of Physics, 53, 1043-1055.

Hake, R.R (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64-74.

Hestenes, D.(1987) Toward a modeling theory of physics instruction, American Journal of Physics, 55, 440-454

Hestenes, D. (1997). Modeling methodology for physics teachers. In E, Redish & J Rigden (Eds.) The changing role of the physics department in modern universities. American Institute of Physics Part II. p. 935-957.

Hestenes, D. & Wells, M. (1992). A mechanics baseline test. The Physics Teacher, 30 (March), 141-158.

Hestenes, D., Wells, M. & Swackhamer, G. (1992). Force concept inventory. The Physics Teacher, 30 (March), 159-166.

Hewitt, Paul G. (1998). Conceptual Physics. New York: Addison-Wesley.

Lederman, N.G. (1992). Students' and teachers' conceptions of the nature of science: a review of the research. Journal of Research in Science Teaching, 29(4), 331-359.

Mazur, E. (1996). Peer instruction: A user's manual. Upper Saddle River, New Jersey: Prentice Hall.

McDermott, L.C. (1993) How we teach and how students learn — A mismatch? American Journal of Physics.61(4)

McGinnis, J. R., Watanabe, T., Shama, G., & Graeber, A. (1997, March). Development of an instrument to measure teacher candidates' attitudes and beliefs about a and science. A paper presented at the National Association for Research in Science Teaching, Oak Brook, Illinois. (ERIC Document Reproduction Service No.ED406201).

McGinnis, J. R., Shama, G., Graeber, A., & Watanabe, T. (1997, March). The assessment of elementary/middle level candidates' attitudes and beliefs about the nature of and the teaching of mathematics and science. A paper presented at the American Educational Research Association, Chicago, Illinois. (ERIC Document Reproduction Service No. ED 407235).

National Research Council (1996). National Science Education Standards. Washington, D. C. : National Academy Press.

National Science Foundation (1993). Proceedings of the National Science Foundation Workshop on the role of faculty from scientific disciplines in the undergraduate education of future science and mathematics teachers. (NSF 93-108). Washington, D.C.: National Science Foundation.

Piburn, M., Sawada, D., Turley, J., Falconer, K., Benford, R., Bloom, I., & Judson, E. (2000). Reformed Teaching Observation Protocol (RTOP): Reference Manual. (ACEPT Technical Report No. IN00-3). Tempe, AZ: Arizona Collaborative for Excellence in the Preparation of Teachers.

Sawada, D. (1999). ACEPT Faculty Enhancement Workshop: Modeling. (ACEPT Technical Report No. SW99-1). Tempe, AZ: Arizona Collaborative for Excellence in the Preparation of Teachers.

Sawada, D. Piburn, M., Turley, J., Falconer, K., Benford, R., Bloom, I., & Judson, E. (2000). Reformed Teaching Observation Protocol (RTOP) Training Guide (ACEPT Technical Report No. IN00-2). Tempe, AZ: Arizona Collaborative for Excellence in the Preparation of Teachers.

Tobin, K., Tippins, D. J., & Gallard, A. J. (1994). Research on instructional strategies for teaching science. In D. White (Ed.), Handbook of research on science teaching and learning (45-93). New York: Macmillan.

von Glasersfeld, E. (1987). Learning as a constructivist activity. In C. Janvier (Ed.) Problems of representation in the teaching and learning of mathematics. Hillsdale, New Jersey: Lawrence Erlbaum.

von Glasersfeld, E. (1989). Cognition, construction of knowledge, and teaching. Synthese, 80 (1), 121-140

Wells, W., Hestenes, D., & Swackhamer, G. (1995) A Modeling method for high school physics instruction, American Journal of Physics 63: 606-619 (1995).

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