2014

The Effects of Modeling Instruction in a High School Physics Classroom

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THE EFFECTS OF MODELING INSTRUCTION IN A HIGH SCHOOL PHYSICS CLASSROOM

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Natural Sciences

in

The Interdepartmental Program in Natural Science

by
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August 2014

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Abstract

The purpose of this research was to study my effectiveness as a high school physics teacher using a traditional approach to instruction compared to a Modeling approach. The study was conducted at a high school near Baton Rouge, Louisiana. Both groups consisted of 1 section of honors physics and 1 section of regular physics each. Conceptual understanding and problems solving gains were measured using pre/post Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT) results, respectively. Students' level of science reasoning was also measured at the beginning of the school year only, using the Classroom Test of Scientific Reasoning (CTSR). The Modeling instruction group had significantly higher conceptual learning normalized gains as compared to the traditional instruction group. The data show no significant difference in the normalized gains in problem solving ability measured by the MBT. A gender bias was seen, with males having higher gains than females. The data showed that honors students had higher normalized learning gains compared to regular students. Students having higher scientific reasoning scores outperformed their peers in conceptual understanding and problem solving.

Introduction

In a speech before the U.S. House of Representatives Committee on Science, President and CEO of the North Carolina Museum of Life and Science, Tom Krakauer, Ph.D. was expounding the virtues of learning from hands-on (science) museum visits. He told the audience,

> When educators and museum professionals talk about *open-ended experience,* this is what we mean. We can teach people what they almost already know. The empowerment of hands-on exhibits is critical because it allows a single exhibit to speak directly to a broad spectrum of visitors who differ in age, educational background, and personal interests. This is learning that celebrates success, not tests for failure.
>
> (Association of Science-Technology Centers Incorporated, 1998)

Teachers play a pivotal role in providing students with open-ended experiences and teaching students "what they almost already know." According to many years of science education research, the biggest impact on student learning is teacher teaching (Sanders, Wright, and Horn, 1997). Other factors can affect student learning positively and/or negatively. Student background, home life, socioeconomic and ethnic factors can also affect learning, but a teacher can have two to three times the impact on student learning compared to any other factor (Sanders, Wright, and Horn, 1997). Non-school factors do affect student achievement, but they are usually outside the teacher's control. Effective teaching can counteract some of the negative outside influences (Sanders, Wright, and Horn, 1997). Effective teachers are best identified by their performance, not by their background or experience. The best way to assess teachers' effectiveness is to look at their on-the-job performance: what they do in the classroom and how much progress their students make.

Apparently, I'm an effective teacher. Based on my school's new evaluation system, I was ranked highly effective. This evaluation had two components: two formal evaluations and my students' performance on an end of course exam. The formal evaluations involved an administrator visiting my classroom and assessing certain criteria: classroom management, level of student engagement, types of questioned asked, etc. In addition, my students' learning was assessed with an end of course exam prepared by the school board. Based on the two snapshot formal assessments and my students' results on the end of course test, I was rated as highly effective. Apparently, I'm an effective teacher, or am I?

According to the National Council for Accreditation of Teacher Education, effective teachers are well prepared and they get results. Being well prepared happens outside of the classroom: learning content, keeping abreast of best practices, and knowing the education research in a particular field. Getting results happens inside the classroom where effective teachers should add value to students. The value teachers add may be tangible and measureable or intangible and not directly measurable. Intangible value may include qualities such as honesty, integrity, punctuality, and patience. For now, in my district, the second half of a teacher's evaluation is based on the tangible and measurable value added to students: learning content.

So what does learning look like for a student taking physics? Did I teach my students? Did they learn? Exactly what did they learn? Since I teach physics, I reflected on what value I should add to my students. What should I teach them? What should they learn? After students complete my class, I want them to have a strong conceptual understanding of mechanics, to be proficient with problem solving algorithms, to be familiar with proper lab techniques (which includes collecting and analyzing data), and to be critical thinkers guided by science reasoning skills. If I only taught them one thing, which one takes precedence? From my list, I realized that conceptual understanding would be the most important value to add to my students. Although the other items are important, conceptual understanding of physics topics is unique to my class, outside of the introduction they may have had in a physical science class. Students entering my class, as seniors, should already have problem-solving, lab, and reasoning skills fairly developed from other science classes. Some of the mathematics techniques we employ are unique to physics instruction: vector analysis, dot & cross products, differentiation, integration, etc. Unless a student has had calculus, he may be seeing some of these techniques for the first time. Even though these techniques are used at times, basic algebra and trigonometry are usually the only tools necessary for solving most of the problems.

Although I was rated by my district as highly effective, I wanted to ensure that I was adding the value that my students would need to become more like reasonable physicists. Was I improving students' conceptual understanding, or were they just memorizing facts for the test? Were they becoming better problem solvers, or were they just grasping at formulas without the understanding behind them? Was I using the best practices and techniques to teach my students physics? Was I just teaching by the method that I was taught? According to physics education research, there are two broad categories of teaching methods: traditional instruction and interactive engagement methods. It turns out that the method of instruction is a crucial factor behind the teacher's and the students' success (Hake, 1998).

The year prior to this study, 2012-2013, I compared the results of my traditional method of instruction to research results that others obtained using either traditional approaches or interactive engagement approaches. I measured my students' conceptual understanding using the Force Concept Inventory (FCI) and their problem solving skills using the Mechanics Baseline Test (MBT). According to research, traditional instruction typically yields low learning gains, whereas interactive engagement methods can yield much higher learning gains. The results of my preliminary investigation of my effectiveness showed that my students had low learning gains in both conceptual understanding and problem solving. My teaching method was as effective as other traditional methods, but not as effective as interactive engagement techniques. Maybe I was not as effective as I could be, and I could improve. At this point, I had two choices: I could do nothing or I could try a more effective approach. Everyone seemed satisfied with the results of my traditional approach, and since I was rated highly effective by my district, why rock the boat? Should I stick by the adage? "If it ain't broke, don't fix it," or should I follow my father's advice? "A job worth doing is worth doing well." I could not ignore the facts; the results of the data. My students deserved better. I was not satisfied, and I believed I could do better.

Modeling instruction has surfaced as an interactive engagement method that has been shown to be more effective at improving student learning over more traditional methods, such as lecturing. Teaching physics using Modeling instruction rather than traditional methods may provide students with the benefit of learning unawares. This is why the Modeling approach seemed so appealing to me. Students learn without knowing it. They learn or refine their thinking by developing mental models that they can use to describe a type of force or a particular kind of motion. The models they develop could be in the form of: diagrams, tables, sketches, graphs, motion maps, algebraic formulas, or a combination of these. They can use these models to extend their thinking by solving related problems. They use these models to predict what could or should happen to an object under certain conditions.

> "The great game of science is modeling the real world, and each scientific theory lays down a system of rules for playing the game. The object of the game is to construct valid models of real objects and processes. Such models comprise the content core of scientific knowledge. To understand science is to know how scientific models are constructed and validated. The main objective of science instruction should therefore be to teach the modeling game"
>
> (Hestenes, 1992)

"Surely the most notable result in the entire experiment was the achievement of the … low-competence students …" (Hestenes & Halloun, 1987). On the rare occasion when I consider leaving the teaching profession, it is usually after a trying day with one of my regular (low-competence) physics classes. I'm not sure why the counselors in the school registrar's office insist that certain students take physics who clearly lack the math skills or the motivation, but I am to play the hand I am dealt. Seemingly, though, each year I am dealt more jokers than aces in my regular physics classes. The results from this Hestenes/Halloun study were powerful motivators for the direction of my research. Seeing similar results with my regular physics classes would help steer me toward embracing the Modeling approach, and maybe keep me at the card table going all in.

Another motivator for using a more interactive approach was Modeling's alignment with the Next Generation Science Standards (NGSS). As shown by Table 1, Modeling instruction meets all of these standards, whereas my traditional approach meets only half at best. For example, referring to the first NGSS, students taught by the Modeling approach would plan and carry out their own investigations. Traditional students would not plan their investigations, because they have already been planned for them. However, they would carry out the investigations. For the second standard, Modeling students would analyze and interpret their data to develop a model to explain the phenomenon, but traditional students would really only analyze their data and align it with a teacher given formula. Their interpretation of the data would be how well it fit the given model or formula, hence the "partial" label.

The difference as to why the Modeling approach meets these standards better than a more traditional approach lies in the framework of each method. The traditional approach is based on teacher monologue, while the Modeling approach is centered around student dialogue.

The traditional approach to teaching science looks something like this: the teacher knows the content, prepares lessons based on carefully thought out lesson plans, demonstrates the concept to the class, lectures as to why the phenomenon occurred, and then provides the theory explaining it. All during this time, the students have been passive observers of the teacher's performance. The next step in the traditional approach has the students practicing how to solve problems based on this newfound knowledge.

Table 1: Next Generation Science Standards

NGSS Standards	Modeling	Traditional
Planning and Carrying Out Investigations	Yes	No, Yes
Analyzing and Interpreting Data	Yes	Yes, Partial
Using Mathematics and Computational Thinking	Yes	Yes, Partial
Constructing Explanations and Designing Solutions	Yes	Partial, Partial
Obtaining, Evaluating, and Communicating Information	Yes	Yes, No, Minimal
Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena	Student Discovered	Teacher Given

"A good lecturer doesn't just deliver facts but models how an expert approaches problems." (Small, 2014). Lectures can be an effective means of teaching, even more so if they are active in nature. A teacher can use a lecture to pose questions and model his thinking to his students. Rather than just having the students sit and receive information, the teacher can pose questions or direct lines of thinking to help the students stay engaged in the discussion. Lectures have their place in education, but they should not be the sole means of the teacher's instructional methods. Teachers should incorporate interactive approaches in their classrooms. Interactive engagement has been shown to improve lectures, classroom assignments, and lab investigations (Hake, 1998).

> Modeling Instruction was developed under the leadership of Dr. David Hestenes when a high school teacher realized that his students, after successfully passing his physics class, had no genuine and deep understanding of the concepts. In the traditional physics classroom, the students are exposed to many formulas and theories and will practice solving problems. In the Modeling classroom, students will do experiments and analyze the collected data to find relationships, which will be presented in graphical, mathematical and pictorial representations. The students will 'discover' the relations themselves and will have a deeper understanding of the concepts taught.
>
> Gwendolyn Hehemann, Program manager for the Science Modeling Institute

As a reflective physics teacher, I have tried to help my students learn without the pressure of having to learn. Years ago, I noticed that when I would help my friends study their material; I would know it before they did. I concluded that I learned it faster, because I did not have the added pressure of having to know it. As a responsible teacher, one of my duties is to be as effective as possible in the classroom. The biggest factor that affects student learning is the teacher teaching (Sanders, Wright, and Horn, 1997). As an inquiring teacher, I need to apprise myself of best practices and pedagogy that align with the standards in my field, namely the Next Generation Science Standards as outlined by the National Science Teachers Association (NSTA).

Literature Review

Research conducted over the past few decades has shown that there are better methods for transferring certain types of information to students other than with a typical lecture, and yet this is one of the primary ways college students are taught, particularly in introductory courses (Mulryan-Kyne, 2010). Some of this research has looked at alternative ways to deliver information to students in college and high school, broadly classified as interactive methods. Others include peer instruction, cooperative learning groups, using case studies, and simulations. Students go from passive receivers of information to active participants in the lecture hall. The teacher or professor goes from being a "sage on the stage" to a "guide on the side."

After analyzing normalized FCI and MBT data, physics students taught using interactive engagement strategies significantly out-performed peers who were taught using traditional lecture methods (Hake, 1998). In this study, Hake collected Force Concept Inventory (FCI) and Mechanics Baseline Test (MBT) data from 6,542 introductory physics students. He was looking for evidence of the effectiveness of interactive engagement (IE). He found that courses using a substantial IE method performed significantly better on the FCI and the MBT when comparing normalized gains. A bias may have been introduced, because the data that Hake used in this study rely on self-reporting by a self-selected population. In addition, Hake relied on the participants in the study to report on teaching approaches, which he did not witness firsthand. What were instructors actually doing in the classroom or lecture hall to constitute "traditional" or "IE"?

Modeling Instruction has surfaced as an IE approach in science classrooms that has gained popularity in many high schools across the nation. Hestenes and Halloun began developing the approach about 30 years ago. The approach grew out of research conducted on improving student achievement in college level physics. Hestenes and Halloun believed that students' understanding and problem solving skills would increase if the students were expressly trained in developing mental models of physics phenomena.

The subjects in the Hestenes/Halloun study were 438 first semester physics students at Arizona State University in the fall of 1983. The students were divided into four groups: 119 in the control group (CG) and 235 split into three treatment groups. All three treatment groups attended one of two lectures conducted by Hestenes in which "The distinctive ingredient of the lectures with greatest relevance to our experiment was a detailed discussion of the descriptive stage in developing particle models…" (Hestenes and Halloun, 1987). The difference in the treatment groups was the recitation: one treatment group (TG1) attended a recitation conducted by experienced graduate TA's who were not aware of the research experiment. The other two treatment groups (TG2 and TG3) attended recitations conducted by Halloun. TG3 received an additional two hour recitation session each week during the first seven weeks. The control group attended lecture and recitation classes that were independent of the treatment groups. The control group was given conventional physics instruction by a professor and TA's who were not aware of the nature and goals of the experiment. The control and treatment groups used the same textbook, had the same daily schedule, the same topics to cover, and the same set of recommended homework problems. The experiment set out to test these two predictions: student achievement in physics can be improved by incorporating a systematic discussion of modeling techniques into class lectures and student achievement can be further improved by employing the method of paradigm problems in recitation classes *(*Hestenes and Halloun, 1987).

The results from this study showed that the treatment groups outperformed the control group on the mechanics diagnostic test and course exams. The researchers claimed the most impressive gains were for the low-performing students, but it was not pointed out that the highest percentage of the low-performing group came from TG3 that received an extra two hour recitation session per week for the first seven weeks. This additional recitation time alone may account for the higher gains for the low-performing group as a whole. In addition, little detail is given to the instructional approach that the control group received. No mention is made to observations either researcher made in the lecture and/or the recitations of the control group.

In the previous study, Hestenes refers to "The distinctive ingredient of the lectures with greatest relevance to our experiment was a detailed discussion of the descriptive stage in developing particle models…" (Hestenes and Halloun, 1987). It is in the descriptive stage where students are learning to express their models with the help of charts, graphs, diagrams, formulas, and written text. Hestenes and Halloun spent time with students explaining model development, model validation, and model implementation. They reasoned that with these skills, students would be better able to understand concepts, solve problems, and make predictions.

Wells et al (Wells M., Hestenes D., and Swackhamer G., 1995) first investigated the effectiveness of this approach in a high school setting. During the 1986-1987 school year, Wells conducted research in his Arizona high school. In this study, there were about 24 high school honors physics students in each of three classes, grouped as follows: modeling, cooperative inquiry, and traditional. Wells was the instructor for the modeling and inquiry classes, and a fellow high school physics teacher was the instructor for the traditional class that served as a control group. The teachers covered the same topics in mechanics on nearly the same timeline. FCI and MBT results of the study supported the conclusions that modeling was superior to inquiry and traditional instruction.

When comparing Wells' Inquiry class to his Modeling class, the instructional difference was that the modeling approach emphasized models and modeling. This resulted in more coherent student investigations and presentations. The overall result was increased coherence of the course as a whole (Wells, et al., 1995).

Following up on Hestenes' claim that "…problem solving in physics is primarily a modeling process" (Hestenes, 1987), Malone conducted studies that correlated knowledge structures and problem-solving behaviors when comparing modeling students to non-modeling students (Malone, 2008). According to the posttest scores, she found that students who learned using the Modeling approach had better knowledge structures and problem solving skills than students who learned with a traditional method.

Malone's first study consisted of 97 first year Pennsylvania high school students during the 2006 school year from four different high schools with similar socioeconomic backgrounds. Two different teachers taught 61 students using the modeling approach and 36 were taught using traditional instruction by two other teachers. All four teachers were veteran teachers with at least 13 years' experience. The modeling teachers had been teaching for 20 and 30 years, and both had 13 years of modeling experience. The other two teachers had been teaching for 13 and 30 years.

A card-sort task was used to assess the organization of knowledge for problem solving. Problems based on one of six deep structure models were placed on cards. Students were asked to group problems based on similarity to solution strategies. Students were not asked to solve the problems, but only sort them into solution type categories. The problems on the cards were originally designed to have two levels: a surface feature and a deep structure model. The problem sets fell into one of six different deep structure models: constant velocity, constant acceleration, Newton's 2^{nd} Law, impulse and momentum, circular motion, or conservation of energy.

Expert problem solvers would group the cards into one of these six deep structure model categories. The cards also had a surface feature. For example, several problems involved an inclined plane, but had different deep structure models: an object on an inclined plane moving at a constant velocity or an object on an inclined plane moving with constant acceleration. Expert problem solvers would group these into two different categories, whereas novice problem solvers would group these into the same category based on their similar surface feature: an object on an inclined plane.

An unexpected observation occurred during this study. Although the cards were designed to have two levels, a third category surfaced during the research. Some students were grouping the cards according to what the problem was asking. For example, several problems might ask for the final velocity, but have different surface features or different deep structure features. Some students would place these cards in the same category based on the question asked. Even with this unexpected distractor category, expert problem solvers grouped the problems based on their deep structure feature. Students were assessed on their conceptual understanding using the FCI and on their problem solving ability using a seven item quantitative problem-solving task developed for the study. The task consisted of one item for each of the deep structure models and the seventh item was a quantitative graphical task. Analysis of the results from the first study showed that the modelers' knowledge organization, conceptual understanding, and problem solving abilities were significantly higher than the non-modelers after a year of physics.

A second study was conducted with 30 students from study 1 having a grade of A or B. 19 were modeling students and 11 were non-modeling students. Video and audio tape transcriptions of these students solving five physics problems were coded and analyzed. Students in study 2 recorded solutions on white boards, and were allowed to refer back to notes and textbooks. There was no time limit for each problem, and retrospective interviews were conducted which allowed students to discuss their thought processes while solving each problem.

The results of study 2 showed that modelers made fewer mistakes and that they discovered and corrected a greater percentage of errors. The study confirmed that modeling students solved problems more like expert problem solvers who base their solution strategy on an underlying concept or model, and that non-modeling students solved problems more like novice problem solvers who rely more on surface features.

Modeling Instruction helps students develop the tools scientists use: critical thinking, developing models, validating those models, and using them to solve problems and make predictions. The more the student develops and uses these modeling techniques, the more his thinking will become more like an expert. For a physics student, thinking like an expert means thinking like a physicist.

> Every physics professor and physics teacher in the country uses diagrams, such as free-body diagrams, while working examples for students. Every textbook has diagrams that accompany the examples in the text. Yet only about 10% of students in conventionally taught pre-calculus introductory physics courses and 20% in engineering physics courses use diagrams to help solve problems…
>
> (Van Heuvelen, 1991).

Students typically view physics as centered on a bunch of formulas, and that the goal is to pick the right formula and solve for the correct unknown. Experienced physicists usually start with a mental model, which may include processes, formulae, sketches, diagrams, or graphs and work from general to specific solutions.

In reviewing the literature on physics education, Van Heuvelen concluded that physics instruction should help students to:

1. Construct qualitative representations of physical processes and problems.
2. Reason about the processes using these qualitative representations.
3. Construct mathematical representations with the help of qualitative representations.
4. Solve problems quantitatively.

These conclusions are in line with the principles of the Modeling approach to physics instruction.

The Modeling approach to teaching physics in my classroom can meet all of these goals: 1. students learn by doing science and not just being told information. 2. The research on Modeling has shown it to be an effective method in increasing student achievement in physics. 3. The technique incorporates all of the standards laid out by the NSTA: Developing and using models, planning and carrying out investigations, using mathematics and computational thinking, and constructing and designing solutions. According to the literature, the Modeling approach would be a wise choice in meeting the goals in my classroom if the results are reproducible. I chose to test the approach in my classroom this past year against my usual traditional approach.

The purpose of this research was to answer these questions: Is Modeling instruction in my classroom more effective than my traditional approach to instruction at improving students' conceptual understanding and problem solving skills as measured by the FCI and the MBT? Are there other factors that influence student learning, besides the method of instruction? Do gender, competence level, and scientific reasoning skills play a role in student learning gains in my classroom?

Procedures

My study took place from August 2013 to March 2014 at a college preparatory (88% graduation rate and 73% attend college) Louisiana high school in East Baton Rouge Parish having about 1500 students and the demographics shown in Table 2.

Table 2: Demographics of the high school student body.

Socioeconomic:	62% full price lunch	30% free lunch	8% reduced lunch	
Ethnicity:	51% Caucasian	46% African American	1% Hispanic	1% Asian
Gender:	51% females	49% males		

The group used for this study consisted of 100 high school students: 92 seniors, 4 juniors, 2 sophomores, and 2 freshmen. All of the students were enrolled in one of my following physics classes: regular physics, honors physics, or AP physics. The control group (1^{st} hour-regular physics & 3^{rd} hour-honors physics) was taught by traditional instruction based on lesson plans from the 2012-2013 school year while the treatment group (5^{th} hour-honors physics & 6^{th} hour-regular physics) received Modeling Instruction as prescribed by the AMTA (American Modeling Teachers Association).

Each class ran for 53 minutes each day, Monday through Friday until February 10^{th}. To make up for winter weather days, the administration added 2 minutes to each class for the rest of the year starting on February 10^{th}, 2014. Although my AP physics class was not a part of the control or the treatment group, I administered pretests and posttests to all of my classes to have some baseline data for further research and possible answers for this study.

I administered the FCI, MBT, and CTSR pretests during the first week of class. The FCI and MBT posttests were administered during the last week of March. A posttest for the CTSR after only one year would presumably yield little to no significant difference in scientific reasoning (Bao, 2009). Each pre and posttest was completed within one class period under no time limit. Most students finished each pre and posttest within 30 minutes, but a few took almost the whole class period. The students are used to pretests from the changes mandated by the state for the new teacher evaluation system. Some students were not present during the testing days and had to make up the tests. I did not want to delay the posttests past March, because students traditionally slack off toward the end of the year, especially after their major English project.

Appendix A shows the order in which the mechanics topics were covered throughout the year for both the control and treatment groups. As an example of the two different teaching approaches, appendix B shows how the projectile motion unit was covered by each method.

Results and Discussion

Two of the goals of my instruction for both groups were to increase students' conceptual understanding of Newtonian physics and to improve physics problem solving ability. Three pretests were administered at the beginning of the school year: the Force Concept Inventory (FCI), the Mechanics Baseline Test (MBT), and Lawson's Classroom Test of Scientific Reasoning (CTSR). The FCI was used to measure the students' conceptual understanding. The MBT was used to measure the students' problem solving ability. The CTSR was also administered to determine the students' level of scientific reasoning at the time of the study. Research claims that there is a link between student learning and science reasoning skills (Coletta, 2007). Statistical analyses were conducted using t-tests with a two tailed distribution and two-sample equal variance type. All effects were considered statistically significant at the 0.05 significance level, and unless otherwise stated, uncertainties are represented as standard error of the mean.

The results of the FCI tests are shown in Figure 1. The pretest scores are not significantly different [$t(83) = 1.44$, $p > 0.05$], showing that the two groups had similar conceptual knowledge at the beginning of the study. Furthermore, their scores of $24 \pm 2\%$ and $28 \pm 2\%$ are consistent with performing a little better than random guessing, which is to be expected from students that have covered some topics in mechanics in freshman physical science. Comparing pre and posttest scores for the FCI, we see that both groups learned. However, the post test scores are significantly different [$t(83) = 2.34$, $p < 0.05$], showing that the treatment group had a significantly higher FCI average score of $45 \pm 4\%$ as compared to the control group's $34 \pm 3\%$.

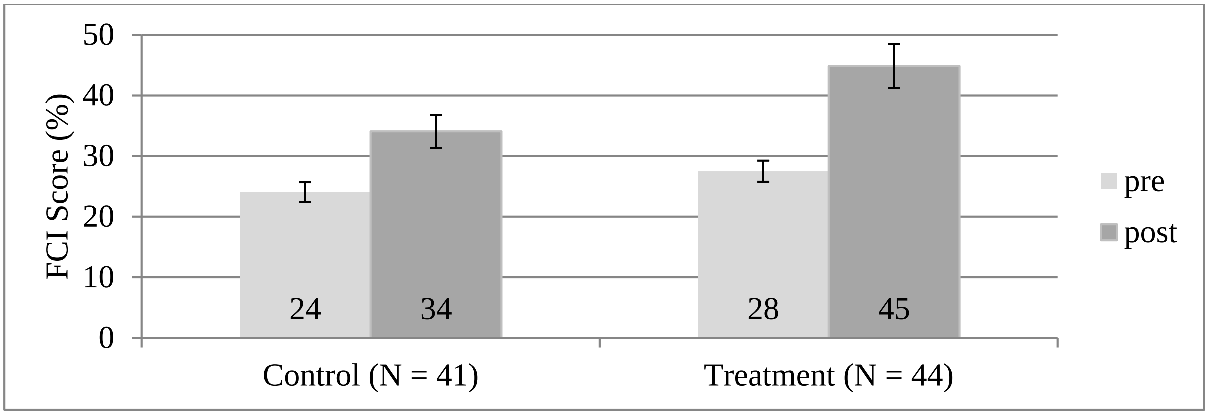

Figure 1. FCI pre and posttest scores in percent. Averages are at the base of each column. Error bars indicate the standard error of the mean.

In their study, Jackson found that students of novice Modelers scored 10 percentage points higher on the FCI posttest than students of traditional teachers (Jackson, 2008). As shown in Figure 1, my Modeling students scored 11 percentage points higher on the FCI posttest compared to my traditional students, although both my average FCI posttest scores (34% and 45%) are lower than the averages reported by Jackson: 42% for traditional and 52% for novice Modelers (Jackson, 2008).

The same pattern is seen with the results of the MBT tests, which are shown in Figure 2. The pretests are not significantly different [$t(83) = 1.02$, $p > 0.05$], suggesting that the two groups had similar problem solving abilities at the beginning of the study. The scores of 22 ± 1% and 24 ± 1% are more consistent with random guessing. As with the FCI, the MBT posttest scores are significantly different [$t(83) = 2.06$, $p < 0.05$], showing that the treatment group had a significantly higher MBT posttest average score of 37 ± 3% as compared to the control group's 29 ± 2%.

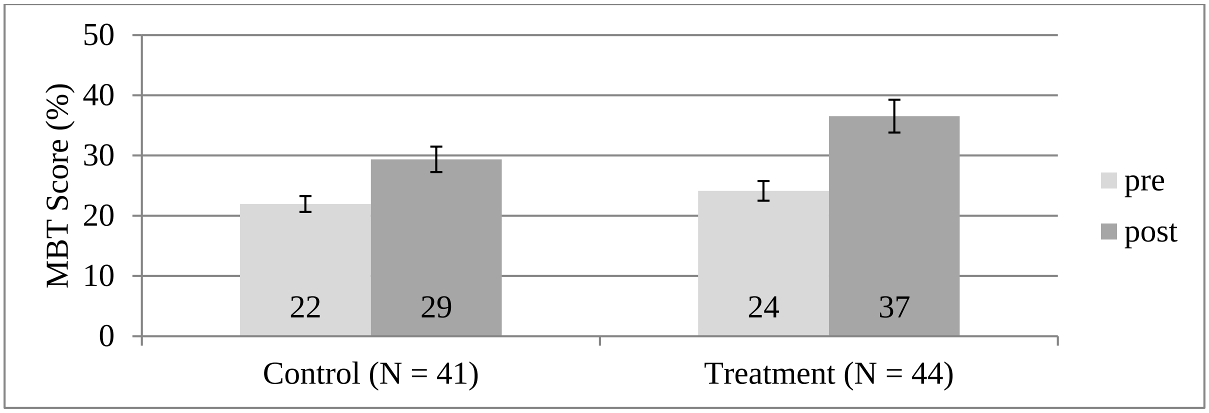

Figure 2. MBT pre and posttest scores in percent. Averages are at the base of each column. Error bars indicate the standard error of the mean.

Results for the CTSR are shown in Figure 3 with average raw scores of 11 ± 1 points and 12 ± 1 points. This shows there was no significant difference [$t(87) = 1.07$, $p > 0.05$] in the two groups' science reasoning skills prior to instruction. Since students' CTSR scores are not expected to increase within a year's instruction, the CTSR was given only as a pretest. The CTSR data from Figure 3 are another indicator of the similarity between the control and treatment groups prior to instruction.

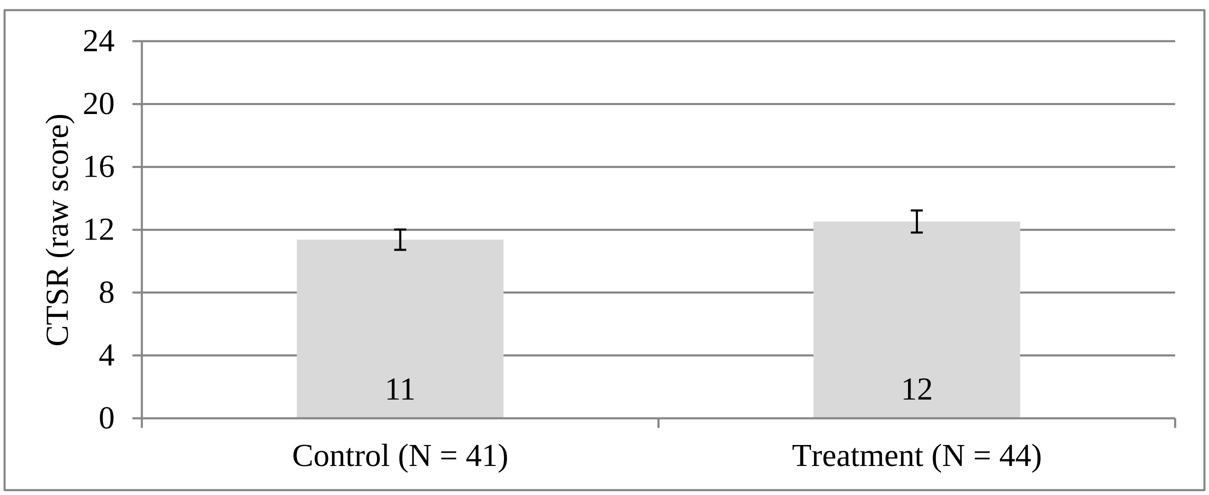

Figure 3. CTSR pretest score out of 24. Averages are at the base of each column. Error bars indicate the standard error of the mean.

As shown by both Figures 1 and 2, we see that both groups gained conceptual understanding and problem solving skills, but the treatment group's gains were significantly higher.

The control group covered impulse and momentum before the posttests, whereas the treatment group did not. Although this fact should not affect the FCI results, it does affect the results of the MBT. The FCI does not assess impulse and momentum, but the MBT has three of the twenty-six items that do. The above averages for the MBT were calculated based on all twenty-six items on the test. If the student responses on the three impulse/momentum MBT items are removed and the tests are rescored based on twenty-three items, the averages are slightly lower: 28 ± 2% and 35 ± 3%. Also, analysis of the twenty-three item test still shows that the treatment group scored statistically significantly higher [$t(83) = 2.16$, $p < 0.05$] on the modified MBT as compared to the control group. According to both assessment tools, the FCI and the MBT, students who received Modeling instruction outperformed their peers who were taught with a traditional approach, although both groups scored below what is typically seen in research studies for Modeling instruction on both the FCI and the MBT (Hake, 2012).

Therefore, both groups learned something, but the Modeling students learned more. I was also curious where my effectiveness as a teacher fell when compared to standard research FCI data. Because pretest scores for students from diverse populations would be different, Hake developed a method for dealing with this issue. In order to compare different high schools, colleges, and universities, Hake formulated what he called normalized gain for the FCI as, g: the ratio of the <u>actual</u> average gain to the <u>maximum</u> possible average gain is determined by (Hake, 1998):

$$g = \frac{\text{post score \%} - \text{pre score \%}}{100 - \text{pre score \%}}$$

In a companion paper, Hake classifies FCI g values as high ($g > 0.7$), medium ($0.3 < g < 0.7$), and low ($g < 0.3$) (Hake, 2012). When looking at Hake's data, students taught by traditional instruction (N = 2084) all fell in the low-g category with $g = 0.23 \pm 0.04$ (sd) for these students. 85% of the students involved in an interactive engagement pedagogy (N = 3741) fell in the medium-g range with $g = 0.48 \pm 0.14$ (sd). The other 15% of those involved in interactive engagement (N = 717) fell in the low-g category. None of his data points fell in the high-g range (Hake, 2012).

Figure 4 shows FCI and MBT normalized gains for the control and treatment groups for my study. The treatment group had statistically significantly [$t(83) = 2.17$, $p < 0.05$)] higher FCI normalized gains: 0.12 ± 0.04 and 0.26 ± 0.05 as compared to the control group. However, the MBT normalized gains showed no significant difference [$t(83) = 1.82$, $p > 0.05$] between the groups: 0.08 ± 0.02 and 0.14 ± 0.03. Based on analyzing the modified MBT, the outcome is the same [$t(83) = 1.78$, $p > 0.05$] , but the averages are a little higher: 0.09 ± 0.03 and 0.16 ± 0.0.

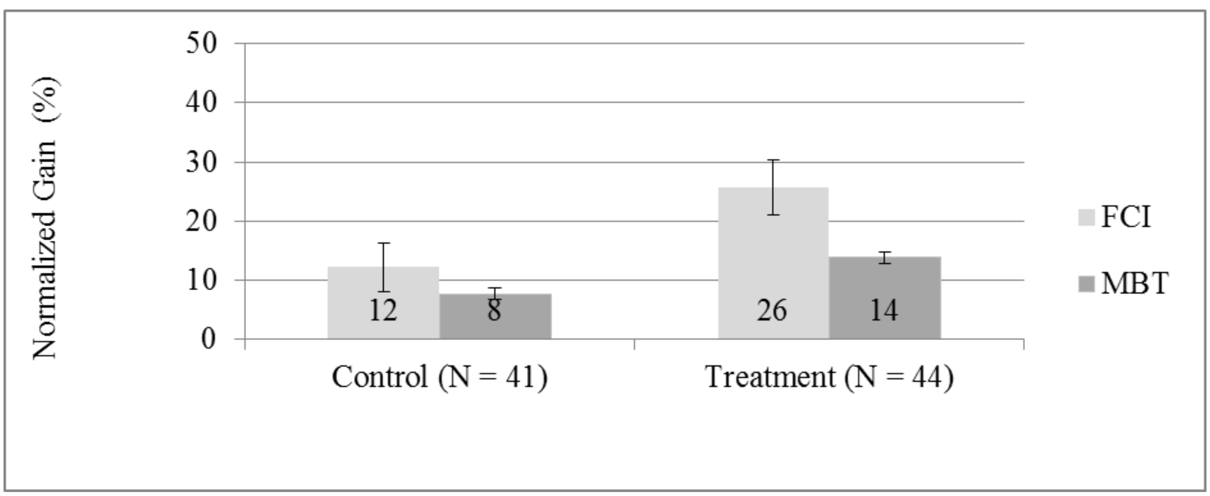

Figure 4. FCI and MBT normalized gains in percent for control and treatment groups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean.

In terms of Hake's categories, my control group's FCI normalized gain would be in the low-g range, whereas my treatment group's FCI normalized gain would be emerging from the low into medium-g range. Reasons for such low gains could be due to the demographics, or the fact that I am a novice Modeler (Jackson, 2008). In addition, my 20 years teaching by traditional methods may have crept into the Modeling treatment. These factors will be discussed in the conclusion.

To study whether the Modeling treatment was affecting the traditional instruction that the control group was receiving, I analyzed FCI and MBT data I collected the year prior to this study, 2012-2013. I decided to use this data to compare to this study's control group, since no Modeling treatment was administered during the 2012-2013 school year. The average FCI normalized gain (13 ± 2%) collected the year (2012-2013) prior to this study, when none of my students ($N = 112$) received the Modeling treatment, showed no statistically significant [$t(151) = 0.11$, $p >> 0.05$] difference from this study's control group's FCI normalized gain of 12 ± 4%. The average MBT normalized gain (0 ± 4%) collected the year prior to this study showed no statistically significant [$t(148) = 1.17$, $p > 0.05$] difference from this study's control group's MBT normalized gain of 8 ± 2%. This year's control group experienced similar gains as last year's students. This data suggest that the instructional approach for this year's control group was not affected by the Modeling approach that the treatment group received, since the control group had similar gains on the FCI and the MBT as in the year when Modeling techniques were not used.

Therefore, students in my classes were seeing gains, but who exactly was seeing these gains and why were they seeing them? Apparently, Modeling instruction was affording greater gains for students, but are there any other factors inherent in the students themselves apart from instructional method that might account for the gains?

Gender differences could be a factor in determining student gains. Research has found that males perform better than females in physics regardless of the type of instruction (Madsen, 2013). Research claims that the Modeling approach to instruction can help decrease the gender gap seen in conceptual understanding (Madsen, 2013), but subsequent studies have not supported this claim (Madsen, 2013), nor do my results. Figure 5 shows FCI normalized gains for male and female subgroups. Analysis showed that males had statistically significantly [$t(98) = 3.15$, $p < 0.05$] higher FCI gains than females: 0.15 ± 0.03 and 0.33 ± 0.05. With the Hake classification, females scored in the low-g range and males scored in the medium-g range.

Similar results were found for the MBT normalized gain as shown in Figure 6. Analysis of the data showed that males had statistically significantly [$t(98) = 3.74$, $p < 0.05$] higher MBT gains than females: 7 ± 2% and 19 ± 2%. Both genders showed learning gains, but the males had higher gains.

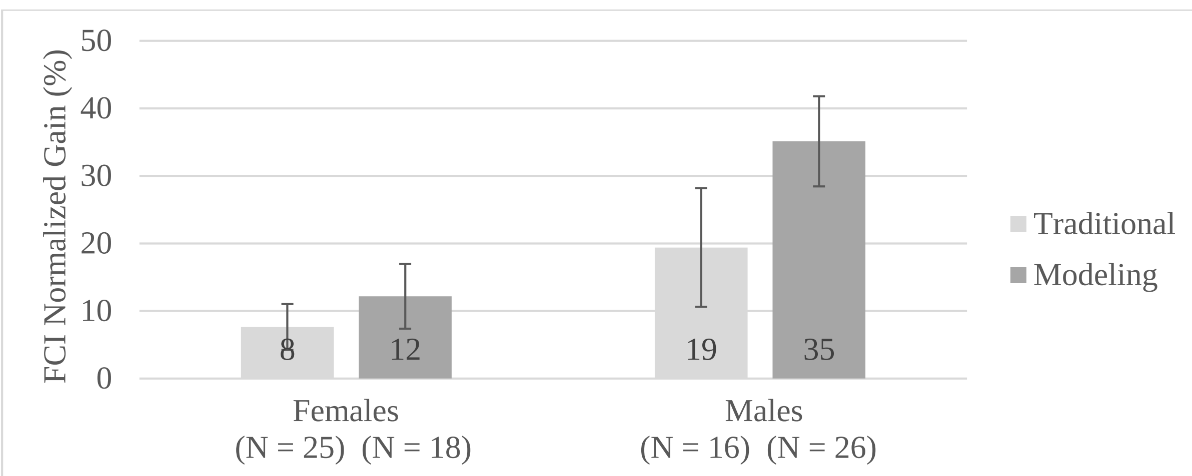

Figure 5. FCI normalized gains in percent for male and female subgroups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean.

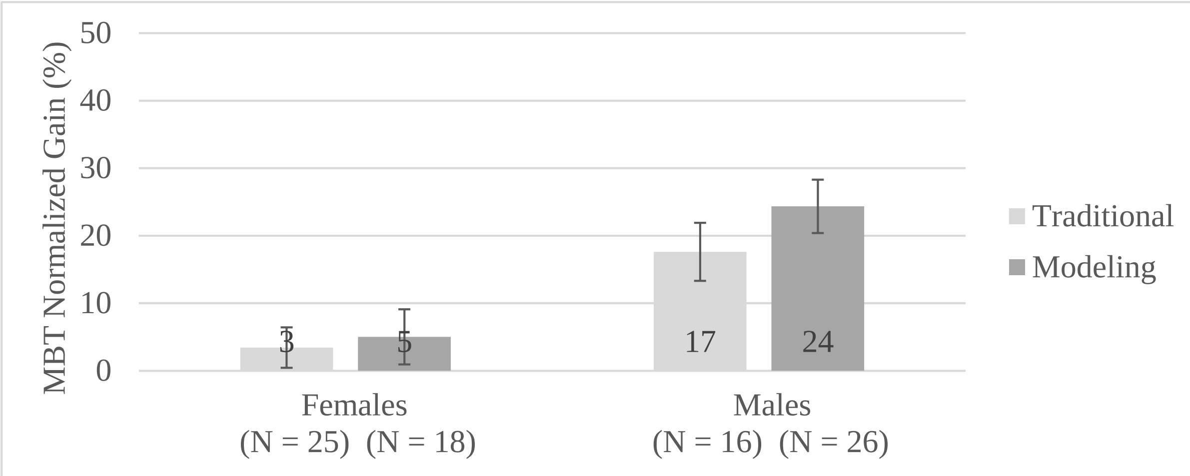

Figure 6. MBT normalized gains in percent for male and female subgroups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean.

As shown in Figure 7, we see the average FCI scores increase from pretest to posttest for both males and females regardless of the method of instruction. Although the males and females had similar starting points, the gender gap increases with both the traditional and the Modeling approach. As can be seen by the posttest results, the Modeling approach is no better than the traditional approach at closing this gap, and may in fact be worse.

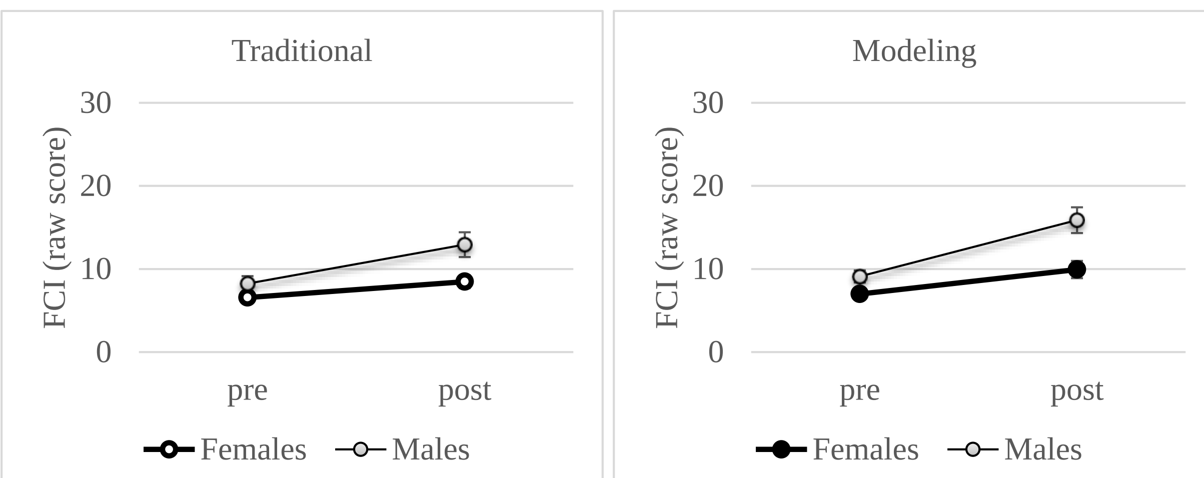

Figure 7. Traditional and Modeling FCI scores (out of possible 30) for male and female subgroups. Error bars indicate standard error of the mean.

Another factor that could account for differences in gains is students' competence level. Competence can come in many flavors, but one that was researched by Hestenes and Halloun was math competence. They found that low math-competence students showed the highest gains on the FCI (Hestenes and Halloun, 1987). In my school, students can take honors classes, regular classes, AP classes and/or a combination of all three. Most of the students are on a particular track (honors, or regular, etc.) by the time they enter the ninth grade. One would think that the regular students would typically have a lower math competence level than the honors students. If this were so, and if the Hestenes/Halloun results were reproducible, I would expect the regular students to show higher gains than the honors students. What I saw, in fact, was the opposite. Figure 8 shows FCI and MBT normalized gains for regular and honors subgroups. Analysis showed that honors students had statistically significantly [$t(42) = 3.88$, $p < 0.05$] higher FCI gains: 0.07 ± 0.04 and 0.39 ± 0.06, as well as statistically significantly [$t(42) = 2.32$, $p < 0.05$] higher MBT gain: 0.07 ± 0.02 and 0.19 ± 0.04 as compared to regular students. With these results, it appears that the Hestenes/Halloun low math-competence college students were not similar to my regular students in terms of their math competence. The honors students would be classified as medium-g in terms of the Hake's classification.

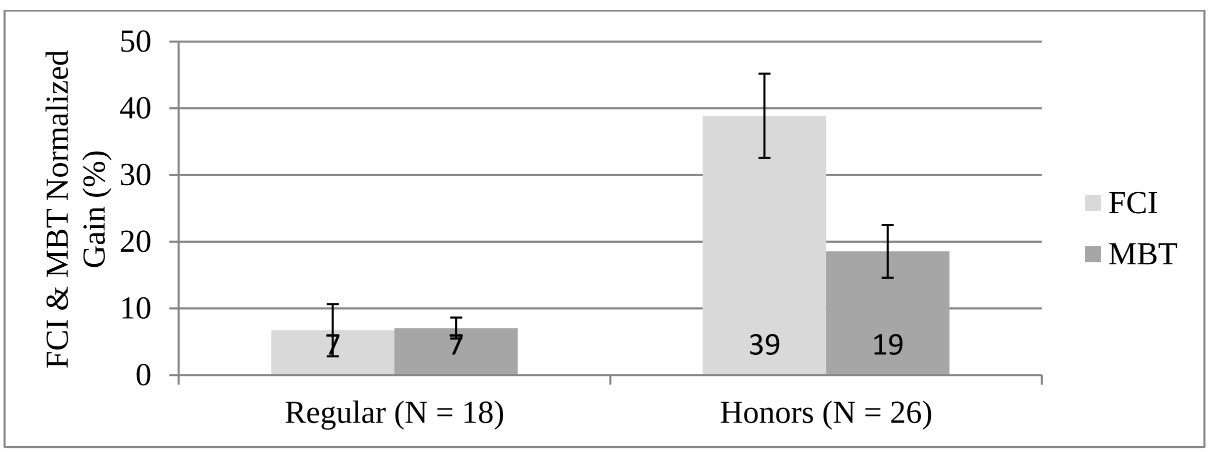

Figure 8. FCI and MBT normalized gains in percent for regular and honors subgroups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean.

The greater number of honors students in the Modeling group as compared to the traditional group was not a factor affecting the learning between the two groups. FCI, MBT, and CTSR pretest, and where applicable, posttest and normalized gains are shown in Table 3.

Table 3: FCI, MBT, and CTSR data for honors subgroups.

Honors students	test	pre (%)	post (%)	norm. gain (%)
Modeling (N = 26)	FCI	30 ± 2	57 ± 5	39 ± 6
	MBT	30 ± 3	52 ± 4	19 ± 4
	CTSR	58 ± 4		
Traditional (N = 19)	FCI	23 ± 2	43 ± 4	24 ± 6
	MBT	26 ± 2	39 ± 4	11 ± 4
	CTSR	58 ± 4		

Statistical analysis of FCI [$t(43) = 1.89$, $p > 0.05$] and MBT [$t(43) = 1.46$, $p > 0.05$] pretest scores showed no statistically significant difference between the honors subgroups. Despite the difference in posttest scores, the FCI [$t(43) = 1.74$, $p > 0.05$] and MBT [$t(43) = 1.42$, $p > 0.05$] normalized gains showed no statistically significant difference.

Some of the differences in gains appear to come from a gender influence and possibly some form of competence level influence. One factor that might explain the two subgroups' higher gains is their scientific reasoning skills. Figure 9 shows CTSR scores (10.0 ± 0.5 points and 14.0 ± 0.7 points) for male and female subgroups. Analysis showed that males scored statistically significantly [$t(83) = 4.20$, $p < 0.05$] higher as compared to females. Researchers have assigned CTSR scores to certain science reasoning levels. Although authors differ somewhat as to where the thresholds occur, Shaw assigns the range between 12 and 18 on this instrument as indicating that the student is in a transitional phase between concrete reasoning and hypothetical-deductive reasoning skills (Shaw, 2012).

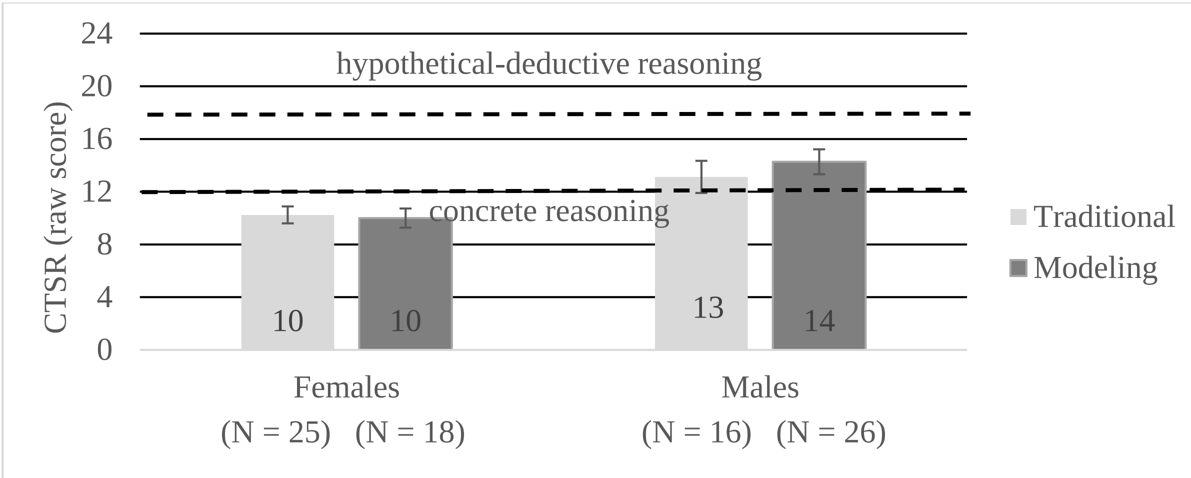

Figure 9. CTSR scores out of 24 for male and female subgroups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean. Thresholds for reasoning level are shown as dashed lines.

Using Newton's second law as an example, a student at the hypothetical-deductive reasoning level would solve a problem as follows. According to Newton's 2nd Law, the acceleration of an object is directly proportional to the net force acting on it and inversely proportional to the object's mass; so if the object's mass is doubled then the acceleration should be cut in half, holding the net force constant. Whereas a student at the concrete reasoning level would rely on one of three formulas, $\sum F = ma$, $a = \sum F/m$, or $m = \sum F/a$ to solve a problem that requires only *one* understanding. The concrete reasoning student sees these three formulas as separate entities unto themselves: three separate, concrete facts rather than one fluid concept.

Both the control and treatment males are in this transitional phase, whereas the control and treatment females remain in the concrete reasoning phase. Figure 10 shows CTSR scores (10 ± 0.6 points and 14 ± 1 point) for regular and honors subgroups. Analysis showed that honors students scored statistically significantly [$t(42) = 3.69$, $p < 0.05$] higher as compared to regular students.

Similar to the male subgroup, the honors subgroup is also in the transitional phase toward hypothetical-deductive reasoning, whereas the regular students remain in the concrete reasoning phase. It is interesting to note that the higher scoring subgroups (males and honors) both had CTSR averages of 14 and the lower scoring subgroups (females and regular) both had CTSR averages of 10.

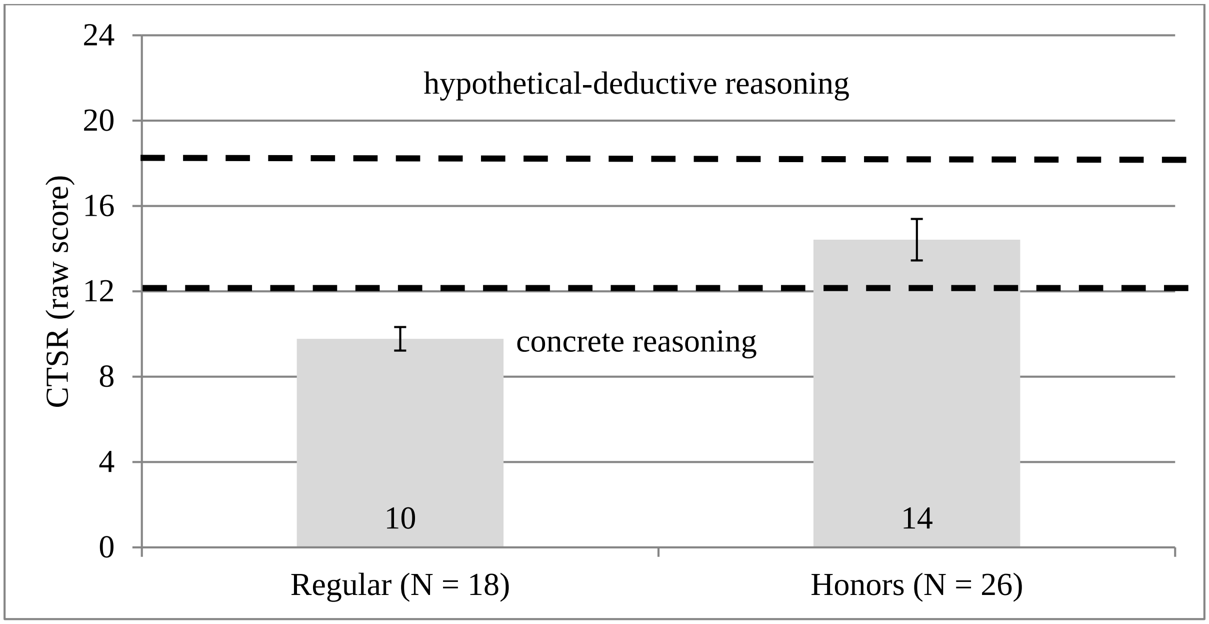

Figure 10. CTSR scores for regular and honors subgroups. Averages are shown at the bases of each column. Error bars indicate standard error of the mean. Thresholds for reasoning level are shown as dashed lines.

I suspected that the learning gains could be linked to students' science reasoning skills. FCI normalized gain was plotted against CTSR raw score as shown in Figure 11. The literature suggests there is a strong correlation between FCI normalized gains and CTSR scores (Coletta, 2007), but the R^2 value I witnessed when plotting all of the students' data was only about 0.4 when comparing FCI normalized gain to CTSR scores. Nevertheless, it seems as if science-reasoning skills *might* be a contributing factor to success on the FCI.

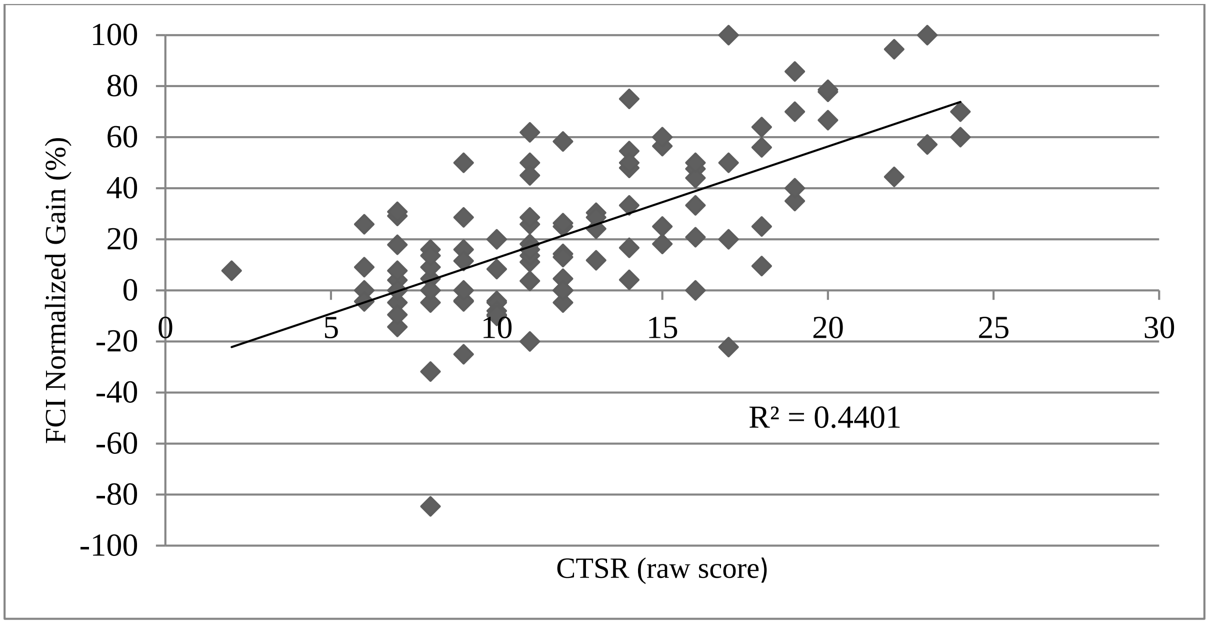

Figure 11. FCI Normalized gain for all students correlated to their CTSR raw scores.

Summary

Although the traditional group and the Modeling group had similar FCI, MBT, and CTSR pretest scores at the beginning of the school year, the posttest scores on the FCI and the MBT indicate that the Modeling group had higher learning gains compared to the traditional group. To see if the Modeling approach was influencing my traditional approach, last school year's FCI and MBT scores were compared to this year's scores. The results showed that my traditional instruction this year was similar to my traditional instruction last year.

Other factors influenced learning gains besides the method of instruction. Males outperformed females on conceptual understanding and problem solving skills. Males also were shown to have higher science reasoning skills. Another factor was competence level. Honors students outperformed regular students in these same areas: conceptual understanding and problem solving. As with the males, the honors students were shown to have higher science reasoning skills compared to the regular students.

According to research, learning gains show a strong positive correlation with science reasoning skills (Coletta, 2007). Although my data showed that there might be a positive correlation between the two, the small sample size rendered the results inconclusive. Besides the small sample size, my being a novice Modeling instructor is also a factor influencing the results of my research. Research has shown that gains are improved as a teacher progresses from the novice Modeler stage to the expert Modeler stage (Jackson, 2008).

Conclusion and Reflection

After analyzing the FCI and MBT data from the previous years' research (2012-2013) and comparing it to published research results, I realized that my teaching was not as effective as it could be. Searching the literature on physics education, Modeling instruction surfaced as a possible means for improving my students' learning. After attending a three-week workshop in New Jersey on how to implement Modeling instruction, I was excited to get back to my classroom to test out the technique. According to the literature, science reasoning may play a role in student learning of physics (Coletta, 2007). In addition to the FCI and the MBT, I also administered the CTSR to determine the students' level of science reasoning. After seeing the effect of science reasoning for my students, tracking science reasoning year to year for each student in my high school may provide our science department with a metric for improving how we teach science. I had asked the department chair at my school if we could give the CTSR to all of the science students at the high school. She agreed, and we asked all of the science teachers to give their students the CTSR during the first two weeks of school. We looked at the results during one of our monthly department meetings, but a detailed analysis is necessary for further discussion of the results.

Why the males in my class outperformed the females is a little disconcerting. I would hope that as a male teacher, I would not introduce a bias favoring the male population. According to my results, CTSR scores seem to be an indicator of the level of learning. Since I gave the CTSR at the beginning of the year, before I could introduce any biases, it seems the males came into my class with the edge already. Tracking science reasoning may need to occur long before the students make it to the high school. With this information, the science departments (district wide) may be able to implement interventions to close this learning gap between males and females. I am not sure if there is anything I could do to decrease this gap since the students come in to my class with a certain level of science reasoning skills. Modeling instruction is supposed to decrease the gender gap, maybe as I become a better Modeling teacher I will see this gap decrease.

As a first year Modeler, I did not see the gains some more seasoned Modelers have seen, but I did fall into the novice Modeler category since my Modeling students scored 11% higher on the FCI compared to my traditional students. After a year of teaching, research on 66 novice Modelers found that their students scored 10 percentage points higher on the FCI than students under traditional instruction. Research has shown that expert Modelers can expect twice the gains of a novice Modeler (Jackson, 2008).

Another factor affecting the gains are the demographics: Whom exactly am I teaching? Students in Louisiana have historically been at the lower end of achievement compared to the national average. Although the demographics in my high school may not reflect the state's demographics, I would rather be at the bottom of the top than at the top of the bottom. The level of the student is multifaceted. At my high school, we differentiate students as honors, regular, or AP. This "simple" delineation has complex implications: the academic level, the motivation, the value of learning, student buy-in, parental involvement, and socio-economic factors. A third factor may have been my unconscious bias towards traditional instruction. Modeling instruction hinges on the students' verbal development of their mental models. They have to say it. Often throughout the year, with my Modeling students, I found myself telling myself, "Shut up!" I have taught using a traditional approach for over twenty years, and it must have had a negative effect on the Modeling approach to the point where I had to scold myself. Lastly, at the time of the posttests, traditional students covered one more unit than the Modeling students: impulse and momentum. Although the FCI does not test these topics, the MBT has three items that test momentum or impulse. Analysis of the twenty-three item modified MBT should correct for that factor. The end of the year was approaching fast, and I did not want to wait any longer to administer the posttests. Students, especially seniors, tend to shut down toward the end of the year, and I wanted them to make an honest effort on the posttest. I made a judgment call, and decided not to wait any longer, even though the treatment group had not yet covered impulse and momentum.

I would hope that as I continue the Modeling approach, I will eventually transition from a novice to an expert Modeler. I plan to continue to use the Modeling Approach, and I hope to influence other teachers to consider the approach in their classrooms. Often throughout the school year, I would tell myself that I need to go through another training workshop on Modeling. I would email my Modeling workshop instructor, periodically throughout the school year with questions such as, "How do you introduce friction?" He would promptly reply and offer well thought out advice. As the year progressed, I would email him less and less. I have encouraged other science teachers to attend a Modeling workshop, but during the year, we are all just trying to keep our heads above water. I think the best approach would be to get buy-in from the school board.

My vision for my high school is to be a center for Modeling workshops. I would like to see my high school host summer workshops not only for our science teachers, but also for the surrounding area. I would like to see a three-way partnership between my school district, the physics department at Louisiana State University, and Arizona State University, the mecca of Modeling instruction. I see myself involved at first as a student at the workshops, then a teaching assistant, to eventually a Modeling instructor.

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Appendix A Topics Covered

Topics Covered

Traditional	Modeling
Measurement	Pressure-volume lab
Error, precision, accuracy	Pendulum lab
1-D Motion	1-D Motion
Vectors	Vectors
Projectile Motion	Newton's Laws
Newton's Laws	Friction
Inertial Mass	Projectile Motion
Work & Energy	Work & Energy
Power	Power
Momentum & Impulse	Uniform Circular Motion
Uniform Circular Motion	
FCI & MBT administered	
Energy conservation (Phet: Skate Park)	Impulse & Momentum

Appendix B Traditional & Modeling Approaches

The difference between Traditional & Modeling

In the traditional approach, students are given 1-2 days of notes on projectile motion. The notes may be accompanied by a demo as I model a concept at the lab station at the front of the class. Students are given the definitions and the equations relating the concepts. After giving the notes and fielding any class questions about projectile motion, students are given worksheets, usually from the Physics Classroom website, to complete in class or for homework. Students work in groups of 2-3 working on the solutions while I walk around the class fielding any questions each group may have. Students are assigned reading from their textbooks about once a week, which corresponds to the notes given in class. Weekly reading quizzes are given to make sure they are keeping up with their reading and/or studying their notes. At some point in the unit, students will complete a confirmation lab where the procedures and steps are mapped out for them. Students usually take a lab quiz after completing the lab to make sure each partner was paying attention to the purpose of the lab. After about 2-3 weeks of these activities, students will complete a unit test.

The sequence for the Modeling approach for the unit on projectile motion is as follows: The unit begins with a demonstration of projectile motion where students discover the motion of the projectile in terms of its x and y components. Before conducting any investigations for themselves, a ball is thrown in an arc for the entire class to see at the front of the classroom. Before I toss the ball, I ask the class for their predictions. I write down a list of any predictions for the entire class to see. At this point, they have been instructed to open their lab books and begin taking notes. After tossing the ball, we discuss the predictions. I continue tossing the ball to different students several times while then asking, “What can we observe?” Students offer their suggestions, and a list is compiled and displayed for the class to see. While looking over the list, I then ask the class, "What can we measure?" The students offer their suggestions, and a list is compiled and displayed. We then go through the exercise of determining which of the variables are dependent, independent, or constant by asking, "What can we change?" Many of the variables are eliminated at this point: the color of the ball, the spin of the ball, etc. We decide as a class which variables we are interested in investigating. Before collecting data, students must pose an objective, which guides the investigation. For example, what is the relationship between the horizontal displacement and the time of flight of the ball? The only instructions given to the students at this point are how to use any equipment, if they have not become familiar with it. Students then collect data on displacement and time, and display their results on white boards: descriptions, tables, graphs, diagrams, motion maps, force diagrams, etc. While they are collecting data, I am walking around to each station and monitoring progress, keeping students on task, or helping with technical/equipment issues. Students discuss their results with each other during a white board meeting where every student can see every other student's results. These results become the students' model for understanding the relationship being studied. This leads to the understanding that the horizontal motion of the ball obeys the constant velocity model, and the vertical motion of the ball obeys the constant acceleration model and that the two motions are independent of each other. The process of collecting, analyzing, displaying, and discussing data takes from 1-3 days. After investigating projectile motion in the lab, students are given a worksheet with no more than ten problems and work the solutions using the model they have developed from the lab. Students work in groups of two to three while I walk around and monitor progress. Completion of the worksheet problems begins in class and is usually completed for homework. The next day, lab groups are assigned the task of white boarding the solution to one or two of the worksheet problems. After about 10-15 minutes, students share their solutions in a white board meeting. The students discuss how and why they came up with the solution, and justify their answers with the concepts developed in the lab.

A quiz on projectile motion is given after each worksheet is completed and thoroughly discussed. A unit review is given for the students to complete and white board. Students complete a lab practical where they must determine where a projectile will land after rolling off a lab counter. Students then complete a unit test on projectile motion. This whole process takes 2-3 weeks to complete.

Appendix C IRB Approval

Application for Exemption from Institutional Oversight

Institutional Review Board
Dr. Robert Mathews, Chair
131 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/irb

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples, or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

-- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-F, listed below, when submitting to the IRB. Once the application is completed, please submit the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://research.lsu.edu/CompliancePoliciesProcedures/InstitutionalReviewBoard%28IRB%29/item24737.html

-- A Complete Application Includes All of the Following:
(A) A copy of this completed form and a copy of parts B thru F.
(B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1&2)
(C) Copies of all instruments to be used.
*If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
(D) The consent form that you will use in the study (see part 3 for more information.)
(E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB. Training link: (http://phrp.nihtraining.com/users/login.php)
(F) IRB Security of Data Agreement: (http://research.lsu.edu/files/item26774.pdf)

1) Principal Investigator: Mark Arseneault **Rank:** Graduate Student

Dept: Natural Science **Ph:** (225) 936-2241 **E-mail:** mark.arseneault@zacharyschools.org

2) Co Investigator(s): please include department, rank, phone and e-mail for each
*If student, please identify and name supervising professor in this space

Dr. Dana Browne
Physics & Astronomy
Professor
(225) 578-6843

IRB# E8349 LSU Proposal #
✓ Complete Application
✓ Human Subjects Training
✓ IRB Security of Data Agreement

3) Project Title: Effectiveness of Modeling instruction on the conceptual understanding of forces and motion as compared to traditional instruction

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/irb
Exemption Expires: 7/14/2016

4) Proposal? (yes or no) No **If Yes, LSU Proposal Number**

Also, if YES, either ○ **This application completely matches the scope of work in the grant**
OR ○ **More IRB Applications will be filed later**

5) Subject pool (e.g. Psychology students) High school physics students

*Circle any **"vulnerable populations" to be used**: (children <18; the mentally impaired, pregnant women, the ages, other). Projects with incarcerated persons cannot be exempted.

6) PI Signature [signature] **Date** 6/24/13 (no per signatures)

**** I certify my responses are accurate and complete.** If the project scope or design is later changes, I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

Screening Committee Action: Exempted ✓ Not Exempted ____ Category/Paragraph 1
Signed Consent Waived?: Yes (No)
Reviewer Mathews **Signature** [signature] **Date** 7/15/13

Vita

Mark E. Arseneault was born in Lowell, Massachusetts in 1966. He attended elementary and middle school at the Sacred Heart School in Lowell. He attended public high school in Chelmsford, Massachusetts and graduated in 1984. He then entered the University of Massachusetts (Lowell Campus) the fall of that same year. He graduated with a bachelor's degree in chemistry from the University of Massachusetts in 1989. After moving to Baton Rouge, Louisiana in 1989, he started teaching in private schools. After 20 years of teaching, he entered the Graduate School at Louisiana State University Agricultural and Mechanical College in 2009. He graduated a year later with his Masters of Arts in Teaching. He has been teaching physics at Zachary High School since 2010, and is currently a candidate for a Master of Natural Sciences from Louisiana State University Agricultural and Mechanical College.