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Experiences of a Novice Modeler Navigating the Alternative Certification Process

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EXPERIENCES OF A NOVICE MODELER NAVIGATING THE ALTERNATIVE CERTIFICATION PROCESS

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ABSTRACT

Interactive Engagement methods of instruction have proven more effective than *Traditional* instruction in terms of conceptual learning in introductory physics classrooms. Modeling instruction is one type of *Interactive Engagement* methodology used in introductory physics at the secondary and collegiate level. This study compares the conceptual gains of students taught by an experienced traditional instructor to the conceptual gains of students taught by a novice, alternatively certified instructor who employs the Modeling methodology in physics classes at a large suburban high school. Pre-tests and post-tests were administered to all groups using validated physics conceptual inventories and a scientific reasoning assessment. AP Physics B mock exam scores were also compiled and analyzed to determine the impact of Modeling instruction on students' problem solving abilities. Additional analyses were conducted to verify the impact of scientific reasoning skills on conceptual learning gains, and to examine whether Modeling instruction closed the "gender gap" in physics. Furthermore, a *post hoc* analysis was performed comparing the conceptual gains of general physics students taught by a novice teacher using traditional instructional methods to the conceptual gains of general physics students taught by the same teacher after completion of a Modeling Workshop. The results indicate that the Modeling methodology is an effective way to increase conceptual understanding of forces and motion in introductory high school physics. The results also support the Modeling Workshop to be an effective and efficient way to train a new, alternatively certified physics teacher.

INTRODUCTION

The Physics Teacher Education Coalition reports that "school districts consistently rank physics as the highest need area among all academic disciplines with regard to teacher shortages".[1] Furthermore, the American Institute of Physics' Statistical Research Center published a report showing that the state in which I teach (Alabama) has lower-than-average availability of physics courses for high school students[2]. These statistics can influence local school districts to drop their physics programs altogether or to employ teachers who might have teaching experience but no physics content knowledge, or to employ teachers who have some physics content knowledge, but no teaching experience. I found myself in the latter group. I was thrust into the physics classroom as a degreed Mechanical Engineer with no teaching experience or educational training.

Embarking on a teaching career and navigating through the alternative certification process after spending some time working in industry and some time as a stay-at-home mom was a challenge. What do I know about teaching? In my experience, science teachers stood in front of the class, lectured, provided a few demonstrations and hands-on experiences, while students sat quietly in their individual desks and took notes. However, it was clear that the educational landscape had changed drastically over the last couple of decades. I was certainly aware of the fact that my own children's teachers were using newer, non-traditional strategies and cooperative learning techniques. In order to be successful in this new career, I needed to fast track my way through the new teacher learning curve and not spend years simply teaching in the same way that I was taught.

In addition to the self-imposed pressure, I also felt pressure from students and parents. There are eager students sitting in classrooms of novice teachers everywhere, hoping that the new teacher is at least as good as the experienced ones. In addition, parental concern adds to the strain when parents perceive that their child is a guinea pig in the classroom of a brand new, alternatively certified teacher. I needed to learn the craft of teaching quickly, using the latest and greatest methods, while concurrently working to enhance dated physics content knowledge, in order to satisfy the most important audience - students and parents.

My first year teaching was not a full year at all, but a partial year of teaching under what is called "emergency certification,"[3] a situation brought about because the high school's general physics teacher left after the first 9-week period of the 2011-2012 academic year. The rest of that year was spent in teacher "survival mode", staying just a step ahead of the students and teaching in a predominantly traditional way. The summer after that first partial year of teaching, I began the Master of Natural Science (MNS)-Physics program at LSU and concurrently began the alternative teacher certification process in the State of Alabama. The alternative certification process was an adequate avenue for learning theory about how to manage a classroom and when to utilize various assessments. The MNS-Physics program was an invaluable opportunity specifically designed to help physics teachers learn how to teach their subject matter most effectively. All of those skills are necessary to be a successful teacher, but the latter was of utmost importance.

The MNS-Physics professors at LSU introduced our cohort to the goldmine that is physics educational research and also explained and demonstrated several different types of scientific inquiry pedagogical approaches. I read many articles and research papers associated with proven effective inquiry teaching strategies, specifically for the introductory physics classroom. I also conveyed some of the new skills I learned over the summer into the next academic year. During my first full year of teaching, I tried to incorporate a "flipped classroom" approach sporadically. I collected pre-test and post-test data from all my general physics students to compare conceptual gains of classes taught traditionally compared to classes taught mostly traditionally with the occasional incorporation of the "flipped classroom" approach. The conceptual gains (as measured by a widely used physics conceptual inventory) of all general physics students that year were, frankly, abysmal. I needed training that is more specific.

During the second summer of the MNS-Physics program, I spent additional time reading studies associated with effective physics teaching methods. It was clear from the research that various types of interactive engagement and inquiry methods were more effective than traditional methods, as measured by several conceptual assessments. One type of interactive engagement method, called Modeling, stood out as an instructional approach that consistently produced higher gains in conceptual understanding and problem solving capabilities of introductory physics students compared to the gains realized from a more traditional approach. Specific research associated with Physics Modeling instruction prompted me to attend a Modeling Workshop at Arizona State University during that same summer, immediately before I was scheduled to teach General Physics for a second full year, in addition to an AP Physics B class and a Principles of Engineering class for the first time. After attending the Modeling Workshop, I was energized and excited to use the modeling approach in my physics classes and test its effectiveness. I had to determine whether the Modeling methodology would work for me, in my classroom, at my school. This study was conducted to determine the impact of the modeling methodology compared to traditional instruction at my high school, looking at conceptual gains, problem-solving ability, scientific reasoning skills, and gender.

LITERATURE REVIEW

Student learning and achievement, if viewed as a change from an initial state to a final state, can be confidently measured using a pre/post-test format. A pre-test can be used to measure students' initial knowledge, and a post-test can be used to evaluate the effect of the instructional method used. In a study[4] by Hake, traditional instructional methods were compared to various interactive engagement methods in introductory physics courses using this pre/post-test analysis. The outcome of the study showed interactive engagement methods to have a distinct advantage over traditional instruction in terms of conceptual gains. The results and implications of this large-scale study were enlightening to many physics educators.

Specifically, Hake gathered pre-test and post-test data using a Mechanics Diagnostic Test and/or the Force Concept Inventory (FCI); in addition, he gathered post-test data from the Mechanics Baseline test. The Mechanics Diagnostic Test and the FCI are both physics concept inventories that assess conceptual understanding of forces and motion, and the Mechanics Baseline Test is a basic mechanics problem-solving assessment. The data used in this study was collected from introductory physics courses nationwide, both at the high school level and the college/university level. All introductory mechanics courses were either labeled *Traditional* or *Interactive Engagement*. Hake defined *Interactive Engagement* methods "as those designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors, all as judged by their literature descriptions." *Traditional* courses were defined "as those reported by instructors to make little or no use of *Interactive Engagement* methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams"[4].

Research supports that one of the most common ways of analyzing pre/post-test data is to calculate and compare the mean normalized gains of the different student groups. Normalized gain is defined as the change in test score divided by the maximum possible increase. Of the 14 traditional classes (n=2,084) and 48 Interactive Engagement classes (n=4,458) analyzed in the study, Hake showed that there was a significant difference in Mechanics Diagnostic/FCI normalized gain between traditional and interactive engagement classes. The results specifically showed the average fractional gains for the *Traditional* classes to be equal to 0.23 ± 0.04 (std. dev.), and the average fractional gains for the *Interactive Engagement* class to be equal to 0.48 ± 0.14 (std. dev.). The results of the *Interactive Engagement* group show a clear advantage over *Traditional* instruction in terms of conceptual gains. Another finding from this study was that *Interactive Engagement* instruction appeared to enhance problem-solving capability, as measured by the Mechanics Baseline Test, even when conceptual understanding was emphasized. The large sample size of this study adds to the credibility of the results.

Hake addressed the possibility that the data collected could have had some inherent bias, surmising that instructors whose students produced relatively higher test scores might be more inclined to share their data and participate in the study. Others see this as a non-issue because even if the final comparison were ultimately between the "best teachers" from both instructional styles, the comparative results would not be affected. Despite any issues with experimental design or how the data was acquired, the results and implications of the study initiated major change in the world of physics education.

In a companion paper, Hake included a categorization of the collected data by type of *Interactive Engagement* method[5]. His intent was to provide readers with a breakdown of the data so that individual instructors could analyze the data for themselves in an effort to determine which type of *Interactive Engagement* method might be most effective. Among the various types of *Interactive Engagement* methodologies, Modeling instruction stood out as one of the more effective methods

Malcolm Wells developed the Modeling approach as part of his dissertation research conducted with David Hestenes and Gregg Swackhamer[6]. The results published from his dissertation presented the initial data that supported the effectiveness of Modeling instruction compared to classes categorized as either cooperative inquiry or traditional. Wells and Hestenes also received assistance from Ibrahim Halloun, who was a graduate teaching assistant compiling statistics for his doctoral research. Through this collaboration, a more refined and structured inquiry methodology (Modeling) was developed, primarily by Wells. Wells combined what he believed to be the most effective mix of strategies from his own experience, in addition to incorporating the educational research at the time, to create his Modeling approach to instruction.

Simultaneously, Halloun integrated his own modeling framework, tailored to his college level students.

In this initial study of Modeling, three different high school honors physics classes, along with three college physics classes, were given pre-tests and post-tests. The two testing instruments used were the Mechanics Diagnostic, developed primarily by Halloun, in addition to a problem-solving test consisting of 24 mechanics questions from 1983 NSTA-AAPT standardized test and 16 questions from PSSC and Harvard Project Physics tests. From this problem-solving test, the Mechanics Baseline test was born.[6]

The study showed the superiority of the Modeling methodology used by Wells over the cooperative inquiry class and the traditional approach. A closer look at post-test scores shows that Wells' Modeling class surpassed his inquiry class by 19% and the traditional class by 15%. A more thorough statistical analysis of the results could have been included in the article; nevertheless, these initial results have been replicated many times, using more developed testing instruments and more detailed statistical analyses. These initial results helped to compel the National Science Foundation to fund the development of Modeling Workshops and the refinement of the modeling methodology, in conjunction with the refinement of the relevant testing instruments.

Some studies[7,8] involving the Modeling methodology also analyze FCI gains in conjunction with the scientific reasoning ability of the students being assessed, as opposed to an isolated FCI analysis. Coletta *et al*. examined whether reasoning ability, as measured by Lawson's Classroom Test for Scientific Reasoning (CTSR), influenced FCI normalized gains among individuals in a particular interactive engagement introductory physics course[8]. The CTSR is a 24-question multiple-choice test that measures the level of a student's scientific reasoning ability.

In the Coletta study, 98 students in various interactive engagement courses in introductory mechanics at Loyola Marymount University, and 199 students in physics Modeling classes at Edward Little High School, were given the CTSR at the beginning of the course and also given the FCI as a pre-test and post-test. After collecting and analyzing the data, they concluded that if a class had an average CTSR score below 50%, it would be reasonable to expect a class average normalized FCI gain of 0.3 or less. In contrast, if a class had an average CTSR score of 90% or more, one might expect a class average normalized FCI gain of 0.6 or more[8]. In separate articles, Henderson and Hake supported a correlation between CTSR score and FCI gains[9,10]. Clement also reported observing a correlation between reasoning level and conceptual gain in physics[11]. These studies prompted the incorporation of both the FCI and CTSR instruments into the experimental design of my study.

A further review of the literature exposed a consistent "gender gap" found in introductory physics. One study by Madsen *et al*. compiled all of the current literature on "gender gap" at that time to look for consistencies, inconsistencies, and possible influential factors[12]. The article states, "Across studies of the most commonly used mechanics concept inventories, the FCI and the Force and Motion Conceptual Evaluation (FMCE), males average pretest scores are always higher than females, and in most cases males posttest scores are higher as well"[12]. This is what is termed the "gender gap". Of particular note is the concept inventory normalized gain "gender gap". The magnitude of the normalized gain on a physics concept inventory assessment is usually greater for males than for females[12]. When the possible factors contributing to this gap were listed, Modeling Instruction was shown to have a demonstrated impact on the FCI gap, according to a study conducted by Eric Brewe *et al*[13].

Madsen's study concerning gender specifically utilized the two most widely used physics conceptual inventories, the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE). A study by R. K. Thornton specifically compared the FMCE and the FCI[14]. Thornton determined that the scores on the FCI and FMCE are strongly related, specifically, for the large population examined (n=3,319), namely, studio physics students at Rensselaer Polytechnic Institute. The FCI % scores and the FMCE % scores have a correlation coefficient of about 0.78 and a slope of approximately 0.54. In this same article, Thornton provides a graph comparing the average FCI and FMCE normalized gains for groups of student having had various instructional experiences with the studio physics environment. All five sub-groups show the average normalized gain on the FMCE to be equal to, or slightly higher than, the average normalized gain on the FCI. Thornton determined that the average normalized gain for a particular sub-group of low-scoring, non-Newtonian thinkers (n=409) was 5% on the FMCE and 12% on the FCI.

In addition to the Thornton study, other studies show a strong correlation between FCI and FMCE normalized gains, and/or show slightly higher normalized gains on FMCE over FCI. In one study by Pollock[15], the FCI and FMCE were both given to introductory physics students who were split into different groups characterized by instructional method. In this study, the median normalized gain on the FCI for all students was 67% and the median normalized gain on the FMCE was 76%, although no uncertainties were provided to decide if these differences are significant.

Research has also shown that there is a difference between the student conceptual gains realized by *Novice* Modeling instructors to student conceptual gains realized by *Expert* Modeling instructors. After attending a Modeling Workshop and thus embarking on the first year of teaching using the Modeling methodology, you are considered a "Novice Modeler", as categorized by a paper written by Jackson *et al*.[16]. Jackson's article presents the results of a comprehensive collection of data from 7,500 high school physics students whose instructors participated in one of the Leadership Modeling Workshops offered from 1995 to 1998. Figure 1 below was taken directly from the referenced article[15] and provides a snapshot of all FCI test data collected during that period, broken down into pre-test and post-test scores from classes taught by Traditional instructors, by Novice Modelers, and by Expert Modeling instructors. It shows that novice Modelers can expect FCI mean post-test scores between those obtained by traditional instructors' students and expert modelers' students.

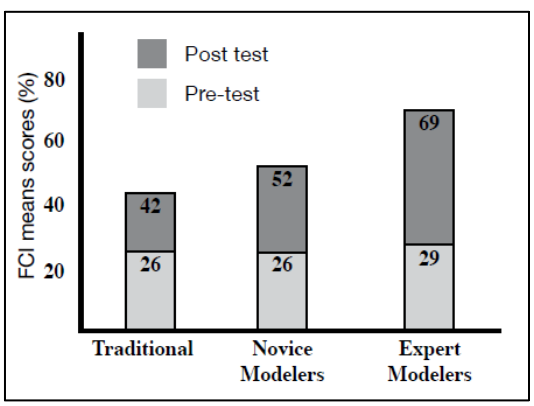

Figure 1: Extracted from "Modeling Instruction: An Effective Model for Science Education"[15]

The statistical analysis and conclusions drawn from the graph in Figure 1 should be further examined because no uncertainties or standard deviations were published with the findings. Nonetheless, considering the large sample size (n=7,500), the general results of this longitudinal study are quite compelling. It is reasonable to assume that a novice modeler may not attain the same results that an expert modeler would attain when comparing conceptual gains.

Considering the research summarized above, one of the goals of my study is to compare student conceptual understanding when taught by a novice Modeling instructor to student conceptual understanding when taught by an experienced Traditional instructor. Another goal of my study is to compare Modeling instruction to Traditional instruction for my General Physics classes. In addition, a gender analysis and a correlation analysis between science reasoning ability and gains in physics conceptual understanding are also included. Before commencing with the details of the study, I will first review the main features of the Modeling approach to science instruction.

MODELING INSTRUCTION

The Modeling methodology has been proven effective, but what is *Modeling*, and what does it look like when practiced in the classroom? The word "modeling" has multiple meanings in different scientific contexts. Hestenes purports that the mere frequency of the word *model* found in scientific research is evidence of its importance. Physical models, graphical models, mathematical models, process models, descriptive models, diagrammatic models and causal models are all used in science and mathematics to represent phenomena. Hestenes explains these various distinctions, but also precisely defines a model: "A model (in physics) is a representation of structure in a physical system and/or its properties."[17]

Physics Modeling instruction and its evolution are explained in several papers written[17, 18, 19, 20] by Hestenes and collaborators. For those unfamiliar with the specifics of Modeling instruction, I will highlight and summarize some of the main ideas presented in these articles and include knowledge acquired from attending the Modeling Workshop. This will show how dramatically different Modeling instruction is from traditional lecture.

Physics Modeling is a student-centered, structured inquiry approach with a modeling framework and emphasis. Modeling instruction is organized around modeling cycles that allow students to develop scientific models of their physical world and then use those models to predict, explain and control physical phenomena. The modeling classroom is student-driven, where students initiate the development of a scientific model by observing a physical situation and then answering three simple questions: "What do I observe?", "What can I measure?" and "What can I change?". These questions prompt collective discussion, and from this discussion, students develop their own experiments, conduct those experiments, and analyze the results. Resulting graphical and mathematical models are then constructed by the students, displayed on portable white boards, and discussed.

Conceptual understanding is stressed in the modeling approach, and the Socratic method of questioning is used to stimulate critical thinking and encourage verbal clarification of conceptual understanding during "board meetings". The "board meeting" was born from the use of dry erase white boards as a preferred method for displaying results to share with the entire class partly because the whiteboard was easy to manipulate and handle in the classroom. Malcolm

Wells is credited with the “invention” of the portable whiteboards as a means to encourage and organize student discourse.

Modeling instruction is believed to be effective for three major reasons. First, Modeling brings classroom instruction closer to emulating real scientific practice. Second, it addresses several major weaknesses in traditional instruction. To address these weaknesses, as compared to traditional instruction, the Modeling method is student-centered (not teacher-centered) and actively engages students in the development and deployment of basic physics models, requiring them to articulate their experimental design, create representations of their data, analyze their findings, and reach consensus with other student groups. The Modeling methodology also directly addresses students’ misconceptions, or preconceptions, about their physical world. Through Modeling, students have a framework for testing and correcting their own ideas. Additionally, the modeling method necessitates cooperative learning (Wells often had students work in groups of 3). Finally, valid research has proven the effectiveness of the modeling method over traditional instruction.

Hestenes gives much credit to Malcolm Wells for creating the initial version of the modeling methodology as it is practiced today. He also credits Wells with developing the modeling cycle. The Modeling Cycle can be considered a refinement of Robert Karplus’ Learning Cycle (Exploration, Invention, Discovery), which is outlined in detail in Appendix A.

In summary, Modeling instruction helps students develop a more coherent, flexible and systematic understanding of physics, as opposed to traditional instruction that tends to be fragmented and diffuse. This is done by focusing instruction around basic models, employing those models to different situations, and then building upon the basic models to focus student attention on the structure of scientific knowledge. It is believed that a majority of the learning takes place when students are required to participate in scientific discourse through Socratic questioning, and defend their experimental findings with the entire class. If students are encouraged and required to explain their conceptual understanding verbally to their peers, and can do so effectively, that is evidence of a deeper level of understanding and accountability of that understanding.

METHODS and DEMOGRAPHICS

During the 2013-2014 academic year, our school's total population was 1,383 students. The school is fairly homogeneous in regard to race and socioeconomic background. The population receiving free and reduced lunch is 9%, and the current race statistics show a student breakdown of 84% Caucasian, 12% African American, 2% Asian, 1% Hispanic, and 1% other. Furthermore, the school's graduation rate consistently hovers around 95%, and the male to female student ratio is nearly 1:1. In addition, the percentage of students who are college bound is approximately 70%.

Specifically, the student sample used in this study includes all 11^{th} and 12^{th} graders who were enrolled in any one of the three physics courses offered at the high school. These three courses are General Physics, AP Physics B and AP Physics C: Mechanics. A detailed description of these courses can be found in Appendix B. With the exceptions of the gender statistic and the college-bound statistic, the sample population is similar in demographics to the school's total population. Physics classrooms typically have a higher percentage of male students enrolled, and my classroom is no exception. During the 2013-2014 school year, the gender breakdown of the sample population was 108 males to 44 females, or roughly 70% male and 30% female. While all of the AP Physics students are college-bound, about 70% of the General Physics' student population intends to go to college, a figure similar to the entire school (≈70%).

During the academic year 2012-2013, I taught six sections of General Physics (n=92) using a predominantly traditional instructional methodology, and I collected pre/post-test data from my General Physics students only. During the academic year 2013-2014, I, the Novice Modeling Instructor (NMI), taught three regular sections of General Physics (n=71) and one block section of AP Physics B (n=12). The other physics teacher, or Traditional Instructor (TI), taught two block sections of AP Physics B (n=44) and one regular section of AP Physics C: Mechanics (n=25). Pre-test and post-test data was collected from all physics classes during 2013-2014.

A more detailed breakdown of all sub-groups included in this study is provided in table below.

Table: Physics class sub-groups included in this study and analysis

Academic Year	Traditional	Modeling
2012-2013	General Physics (n=92) Novice Traditional	
2013-2014		General Physics (n=71) Novice Modeler
	AP Physics B (n=44) Experienced Traditional	AP Physics B (n=12) Novice Modeler
	AP Physics C (n=25) Experienced Traditional	

The objective of this study was to collect pre-test and post-test concept inventory data and scientific reasoning data in order to analyze and compare the results among the different groups to determine the impact of Modeling instruction compared to Traditional instruction. The three diagnostic assessments used in this study include the FCI, FMCE and Lawson's CTSR.

The Force Concept Inventory (FCI) is a concept inventory multiple-choice test (30 multiple-choice questions) assessing conceptual understanding of the topics of forces and motion. It is a validated testing instrument and is widely used for physics educational research purposes. Research supports that an FCI score of ≥60% can be considered the *Early Newtonian Thinking* threshold and an FCI score of ≥85% can be considered the *Newtonian Thinking* threshold.[21]

The Force and Motion Conceptual Evaluation (FMCE) is also a multiple-choice conceptual evaluation (47 multiple-choice questions) used to assess a student's conceptual understanding of forces and motion. Like the FCI, the FMCE can be used as a diagnostic tool and/or for course evaluations. Lawson's Classroom Test of Scientific Reasoning (CTSR) was also utilized in this study because of its validity as a scientific reasoning ability assessment and its popularity among Science and STEM (Science, Technology, Engineering and Math) educators and researchers.

The CTSR includes 24 multiple-choice questions and tests the following categories of reasoning ability: correlation reasoning, probability reasoning, control of variables, proportional reasoning, deductive and inductive reasoning, and hypothesis evaluation. AP Physics B mock exam data was also analyzed in an effort to formulate determinations about the problem-solving capabilities of the two AP Physics B sub-groups.

The two sub-groups taught by the experienced Traditional instructor and the sub-group taught by the novice Traditional instructor navigated through the mechanics curriculum via lessons consisting of a blend of demonstration, lecture, and verification lab experiments, in addition to substantial problem solving practice. The two sub-groups taught by the novice Modeling instructor using the Modeling methodology utilized the mechanics Modeling curriculum and had some additional problem-solving practice. In the classes taught by the novice Modeling instructor, the Modeling framework and sequencing was adhered to as per the curriculum provided at the Modeling Workshop (see Appendix C for an example of a Modeling unit and sequence). A typical Modeling unit and sequence takes approximately two to three weeks to complete.

Although all sub-groups had approximately the same number of instructional hours, the APB courses met for a block period every day, while the APC and General Physics courses met for one regular class period three days a week in addition to one block day per week. The post-tests were given immediately after mechanics instruction for each group. This meant that the APB sub-groups took the post-test just before the second 9-week period ended, while the APC and General groups took the post-test after the third 9-week period. Although the number of instructional hours were essentially the same for all four sub-groups, the time interval between pre-test and post-test for the APC Traditional and General Physics classes was approximately 50% longer.

In addition to the different modes of instructional methodology of the two instructors involved in this study, there is a significant difference in the experience and educational backgrounds of the two instructors. The Traditional instructor earned Bachelor's and Master's degrees in education, has 20+ years of science teaching experience (Physics and Chemistry), is a Nationally Board Certified Teacher, and is the head of the Science Department at the school. The Novice Modeling Instructor has a degree in Mechanical Engineering, had less than two full years of teaching experience at the beginning of the study, and was concurrently navigating through the alternative certification requirements. It is likely that a combination of these other uncontrolled variables may have had an effect on the results. Nonetheless, both smaller and larger sample size studies comparing Modeling/IE to Traditional methods included different instructors with various styles, educational backgrounds and experiences. I commenced the study with the full cooperation of the other physics teacher at my high school, and we both wanted to let the data tell its story.

An additional analysis was conducted comparing Modeling instruction to Traditional instruction while keeping the instructor variable constant. Specifically, the conceptual gains realized by the General Physics population taught by myself (Novice Modeler) during the academic year 2013-2014 was compared to the conceptual gains attained by the General Physics population taught by myself (Novice Traditional) during the academic year 2012-2013. Academic year 2012-2013 was my second year (first full year) of teaching, and I employed a mostly traditional style of instruction. The FMCE was administered to all General Physics students during the 2012-2013 school year, and the FCI was administered to all General Physics students during the 2013-2014 school year. It is unfortunate that I did not use the same instrument both years; however, as described in the *Literature Review* section these diagnostic assessments show strong a correlation to each other, thus the comparison is analyzed in light of that research.

The General Physics students from 2012-2013 were originally broken down into two groups, a control group (n=52) and an experimental group (n=40). The control group was taught using mostly traditional methods. The experimental group used these same traditional methods with an additional, occasional "flipped classroom" element, which consisted of assigning video lectures and video problem-solving instruction to be done at home. These two groups showed no statistical difference in gains that year, so the gains of the combined population of General Physics students from that year (n=92), are ultimately compared to the conceptual assessment gains of the total population of General Physics Modeling students from academic year 2013-2014. Given the minimal change in instruction, which remained essentially teacher-centered, this combined group was included as a traditional model group for the purposes of the present study.

DATA ANALYSIS and RESULTS

Statistical analysis techniques utilized in the examination of test data include t-tests and analysis of variance (ANOVA) to determine whether there were any statistically significant differences between the groups being compared. Where applicable, the alpha value was set at 0.05 for all statistical analyses conducted in this study.

Figure 2 below includes both the mean pre-test and the mean post-test results of the FCI for all four sub-groups.

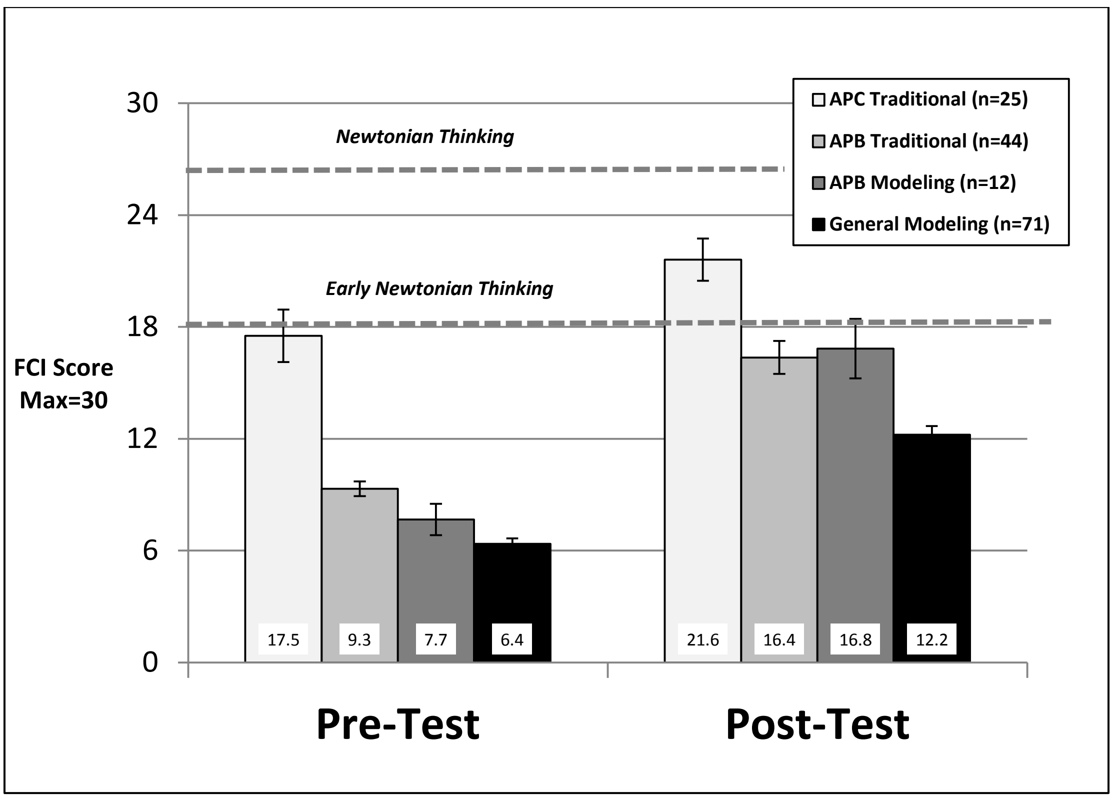

Figure 2: FCI Pre-Test and Post-Test Results for 2013-2014 Academic Year groups. The accepted thresholds for FCI competence are shown as dashed lines.

The maximum possible score on the FCI is 30. It is clear from the graph that the AP Physics C: Mechanics sub-group showed a mean FCI pre-test score that was significantly higher than all other groups. A detailed statistical analysis of the pre-test data shows that the APC Traditional group had a mean FCI pre-test score of 17.5 ± 1.4. The APB Traditional group had a mean FCI pre-test score of 9.3 ± 0.4. The APB Modeling group had a mean FCI pre-test score of 7.7 ± 0.8, and the General Modeling group had a mean FCI pre-test score of 6.4 ± 0.3. The single-factor ANOVA results of the FCI pre-test scores are $F(3, 148) = 58.1$, $p < 0.001$. A post-hoc Bonferroni-adjusted comparison was then conducted to understand specifically which groups were statistically dissimilar.

An analysis with t-tests showed that the APB Traditional sub-group had an FCI pre-test score that was statistically higher than the General Modeling sub-group's FCI pre-test score. The APB Traditional and APB Modeling sub-groups showed no statistically significant difference in mean FCI pre-test scores. Furthermore, the APB Modeling and General Modeling sub-groups showed no statistically significant difference in mean FCI pre-test scores.

These FCI pre-test results align with the fact that all APC Traditional students at the high school have already taken and passed the AP Physics B course. For the APC Traditional sub-group, it is essentially their second time taking high school physics. This group clearly attained and retained conceptual knowledge from taking and passing the AP Physics B course the previous year. Furthermore, the other sub-groups (APB Traditional, APB Modeling, and General Modeling) are primarily comprised of students who are taking physics for the first time.

In spite of inherent differences among the groups, all four sub-groups show statistically significant growth from FCI pre-test to post-test, so all groups improved in conceptual understanding of the material. The APB Modeling group showed growth from that was in line with the results obtained by *Novice Modelers* per the Jackson article[15]. The APB Traditional group showed growth that was lower than that realized by *Expert Modelers* in that same article. In an effort to further compare the conceptual gains among the groups, FCI normalized gain was calculated for each group and a statistical analysis was performed.

Comparing normalized gain among groups is an acceptable way to compare groups that have inherent dissimilarities in their population, which is the case in this study. The normalized gain (g) was calculated using the formula below.

$$g = \left(\frac{posttest\ raw\ score - pretest\ raw\ score}{max\ raw\ score - pretest\ raw\ score}\right) * 100$$

This calculated normalized gain (g) is typically expressed as a percentage.

Figure 3 below shows the FCI normalized gains for all four sub-groups. Of the four sub-groups, the only two groups that showed a statistical difference in FCI normalized gains are the APB Modeling sub-group and the General Physics Modeling sub-group.

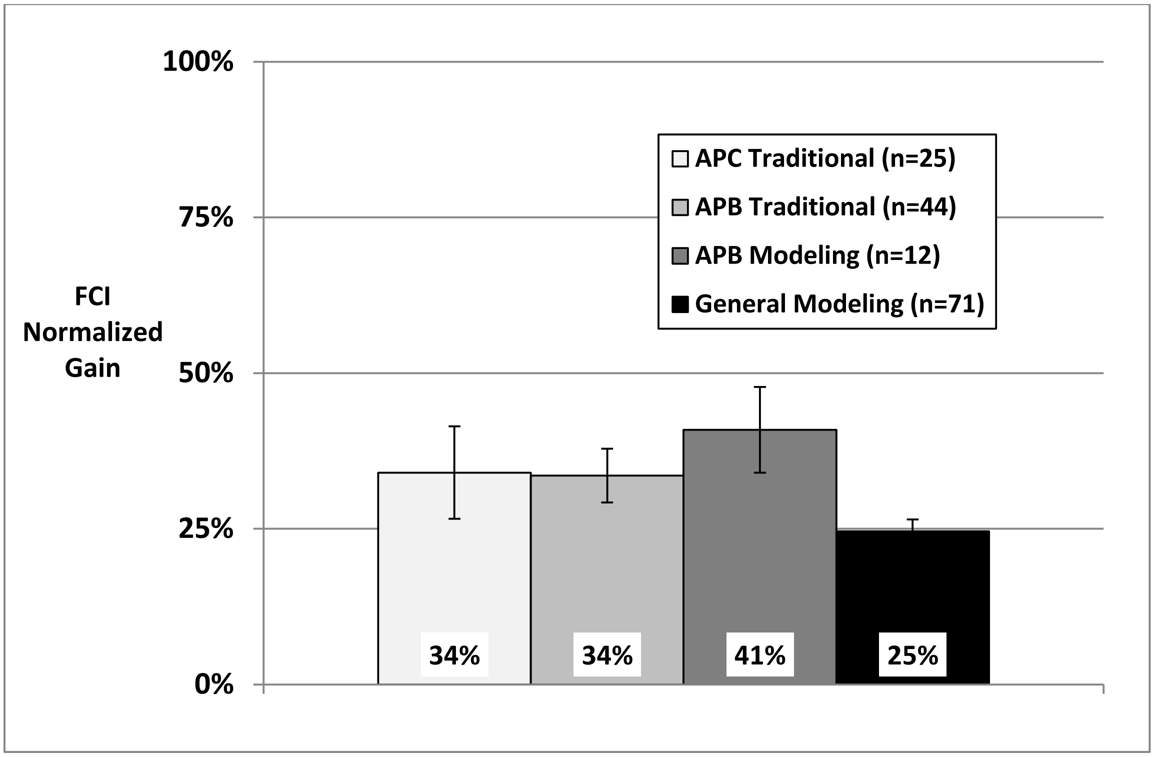

Figure 3: FCI Normalized Gains (Academic Year 2013-2014)

A detailed statistical analysis showed that the APC Traditional group realized a g = 34% ± 7%, the APB Traditional group realized a g = 34% ± 4%, the APB Modeling group realized a g = 41% ± 7%, and the General Modeling group realized a g = 25% ± 2%. The single-factor ANOVA results of FCI normalized gains are $F(3, 148) = 2.9$, $p = 0.04$, which shows that there is at least one group that is statistically dissimilar, although this is not as dramatic a result as the two previous ANOVA results. After a post-hoc Bonferroni comparison was conducted, it was confirmed that the only two groups that show a statistically significant difference in FCI normalized gain are the APB Modeling sub-group and the General Modeling sub-group. This could possibly be explained by the fact that these two groups had a statistically significant difference in scientific reasoning ability, in addition to a difference in time between pre-test and post-test administration of the FCI.

When the normalized gain results were compared to those results from the Hake article[4], all four sub-groups showed a normalized gain between Hake's *Traditional* group ($g = 0.23 \pm 0.04$ std dev.) and Hake's *Interactive Engagement* group ($g = 0.48 \pm 0.14$ std dev.), with the AP classes showing normalized FCI gains significantly higher than Hake's *Traditional* instruction group. However, the General Modeling group did not see a normalized gain that was significantly different from Hake's *Traditional* group. CTSR ability was not presented with the Hake study, so it is possible that scientific reasoning ability could have played a part in that result.

As mentioned earlier, during the academic year 2012-2013, I taught my General Physics students using predominantly traditional methods with all of my classes. In that year, I did attempt to change instruction for an experimental sub-group by adding a "flipped classroom" element; however, the experimental design had inherent flaws, and the results showed no statistical difference among the control and experimental groups' gains from that year, leaving the two groups with essentially the same instruction and gains. This justified combining those two groups into one group of General Physics students (n=92) taught traditionally by me prior to Modeling training.

Figure 4 on the following page compares the FMCE normalized gain of my traditionally taught 2012-2013 General Physics students and the FCI normalized gain of my General Physics students who were taught using the Modeling methodology in the 2013-2014 academic year.

The results appear to show that the General Physics group taught using the Modeling methodology has a distinct advantage in terms of conceptual normalized gain. Specifically, the General Physics Traditional group from 2012-2013 showed a concept inventory (FMCE) normalized gain of 5% ± 1%, and the General Physics Modeling group from 2013-2014 showed a concept inventory (FCI) normalized gain of 25% ± 2%. Because of the relatively larger sample sizes and a common instructor, this is somewhat compelling evidence in favor of the Modeling methodology over Traditional instruction for conceptual understanding.

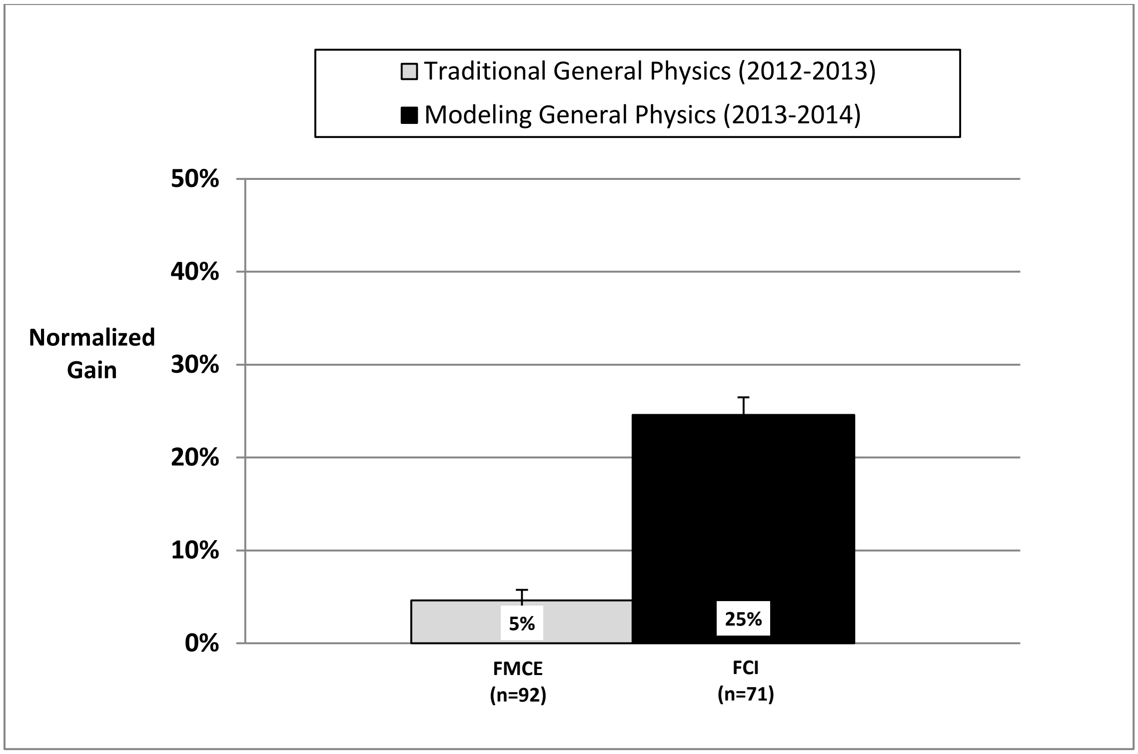

Figure 4: Conceptual Normalized Gains General Physics (Traditional vs. Modeling)

Although Figure 4 compares two different conceptual inventories, some published evidence actually supports that the normalized gain on the FMCE is typically equal to or higher than the normalized gain on the FCI for a given population[9]. In that case, if I had given the FCI in 2012-2013, that group's FCI normalized gain would likely have been equal to or less than 5%. Likewise, if I had given the FMCE in 2013-2014, that group's FMCE normalized gain would likely have been equal to or higher than 25%. Either of these scenarios would have widened the gap in favor of the Modeling methodology, not closed it.

According to a study[8] by Coletta, *et al*., the scientific reasoning ability of the students can affect FCI gains, so characterizing the sub-groups in terms of their scientific reasoning capabilities allows for a more accurate and complete interpretation of subsequent FCI results. Studies that utilize the CTSR as a diagnostic instrument typically give the CTSR once per year as a pre-test. The CTSR was given as a pre-test and post-test because I was curious to see whether significant gains in scientific reasoning capability could be realized in one semester.

Figure 5 below includes both the mean pre-test and the mean post-test results of the CTSR for all four sub-groups from academic year 2013-2014. This bar graph represents the raw CTSR score out of a possible max of 24. Only one of the sub-groups (General Modeling) showed a significantly lower mean CTSR pre-test score than the other groups.

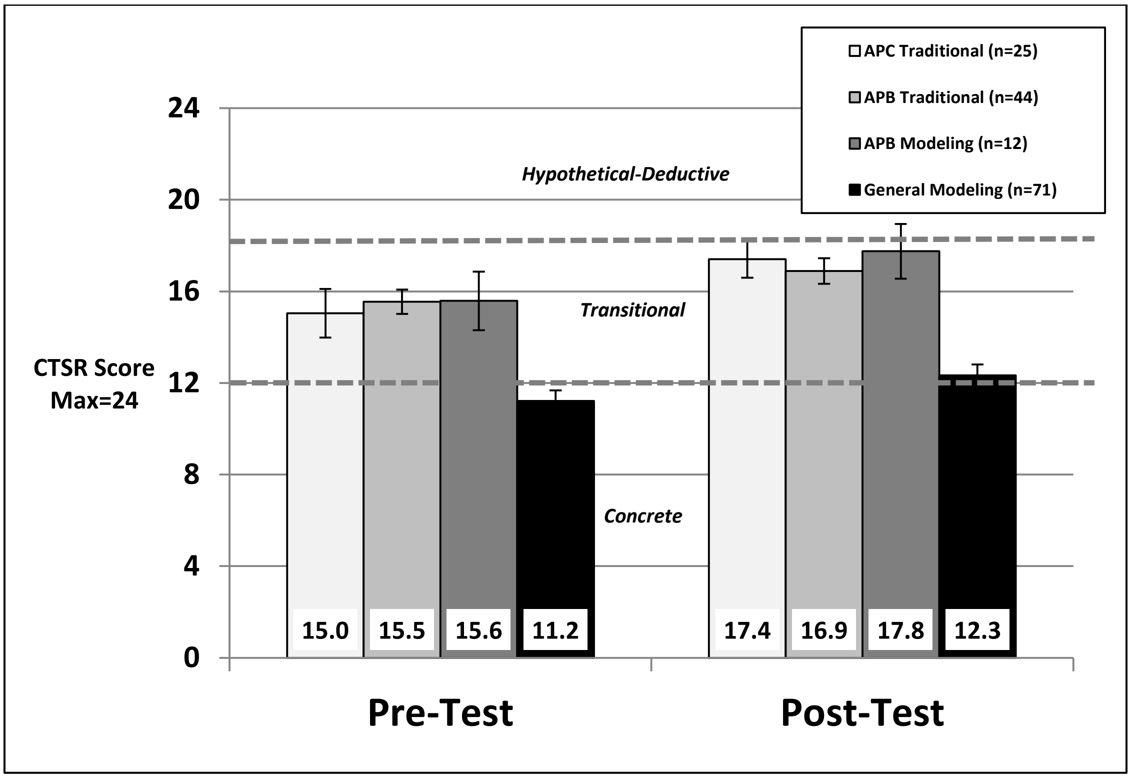

Figure 5: CTSR Pre-Test and Post-Test Comparison (Academic Year 2013-2014) The accepted thresholds for reasoning are indicated as dashed lines.

A detailed statistical analysis of the pre-test data shows that the APC Traditional group had a mean CTSR pre-test score of 15.0 ± 1.1. The APB Traditional group had a mean CTSR pre-test score of 15.5 ± 0.5. The APB Modeling group had a mean CTSR pre-test score of 15.6 +/- 1.3, and the General Modeling group had a mean CTSR pre-test score of 11.2 ± 0.5. The single-factor ANOVA results of the CTSR pre-test scores are $F(3, 148) = 13.0$, $p = 0.0$, which shows that there is at least one group that is statistically dissimilar. After a post-hoc Bonferroni comparison was conducted, the only dissimilar group in terms of CTSR pre-test score was confirmed to be the General Modeling sub-group. In addition, t-test results showed that none of the sub-groups showed statistically significant gains in scientific reasoning ability after one semester. From this collection of CTSR analyses, it is reasonable to infer that the students in the General Modeling group may not have the scientific reasoning skills necessary to realize the same magnitude of conceptual gains as the other three AP Physics sub-groups. The graph also shows that most of the groups fall into the transitional phase between concrete science reasoning skills and hypothetical-deductive science reasoning skills. These CTSR score categories were established in an article written by K. Shaw.[22]

With at least some compelling evidence in favor of the Modeling methodology over traditional instruction as measured by conceptual inventories, it is also informative to compare problem-solving ability among the sub-groups. Unlike the Hake study, I did not use the Mechanics Baseline Test as a post-test; however, I did collect and analyze data from the AP Physics B Mock Exam, for the two APB sub-groups from 2013-2014. The APB Mock Exam could be largely considered a problem-solving test. Figure 6 on the following page shows a histogram comparison of the raw AP Physics B Mock exam scores of the two APB groups, one Modeling and one Traditional, from Academic Year 2013-2014.

The max possible raw score on the AP Physics B exam is 160. Because the APB Modeling group has such a low number of students in the population (n=12), there is not enough data to draw any definitive conclusions; however, the results are interesting, nonetheless. From the histogram, we can see that these groups are certainly not obviously different. Furthermore, the ranges of scores for both APB sub-groups are similar. The mock exam raw score range for the AP Physics B Traditional sub-group is 26-110, and the raw score range for the AP Physics B Modeling sub-group is 30-108.

In addition, the mean AP Physics B raw scores for both groups were statistically similar. The mean APB exam score for the APB Modeling groups was 62 ± 8.0, and the mean APB exam score for the APB Traditional group was 65 ± 3.2, out of a possible max of 160 points. This additional evidence further supports that there is likely no difference in problem solving ability between the two groups as measured by the AP Physics B Mock Exam.

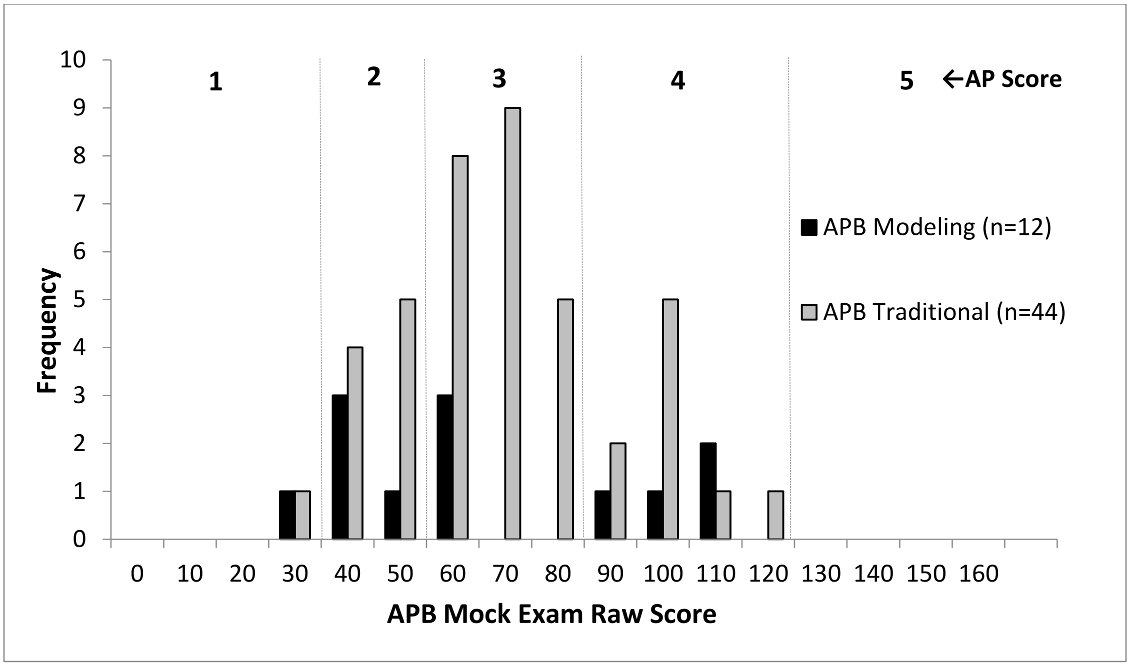

Figure 6: AP Physics B Mock Exam Raw Scores (Academic Year 2013-2014). The common thresholds for each AP score are shown as vertical dashed lines.

In addition to comparisons of scientific reasoning and conceptual learning gains, a supplemental analysis was conducted to determine whether a "gender gap" existed on the FCI. Figures 7 and 8 on the following page include gender comparisons of FMCE pre-test and post-test scores from 2012-2013 and FCI pre-test and post-test scores from 2013-2014, respectively.

The statistical analysis showed that there was no significant difference between female FMCE pre-test score and male FMCE pre-test score for the General Physics Traditional sample population in the 2012-2013 academic year, thus a significant "gender gap" was not present at the outset. The FMCE pre-test t-test resulted in a $p = 0.36$. A gender analysis of the FMCE post-test scores was then conducted to determine whether a "gender gap" was present after Traditional mechanics instruction. The analysis showed that there was not a significant "gender gap" for the post-test either. The FMCE post-test t-test resulted in a p-value=0.6.

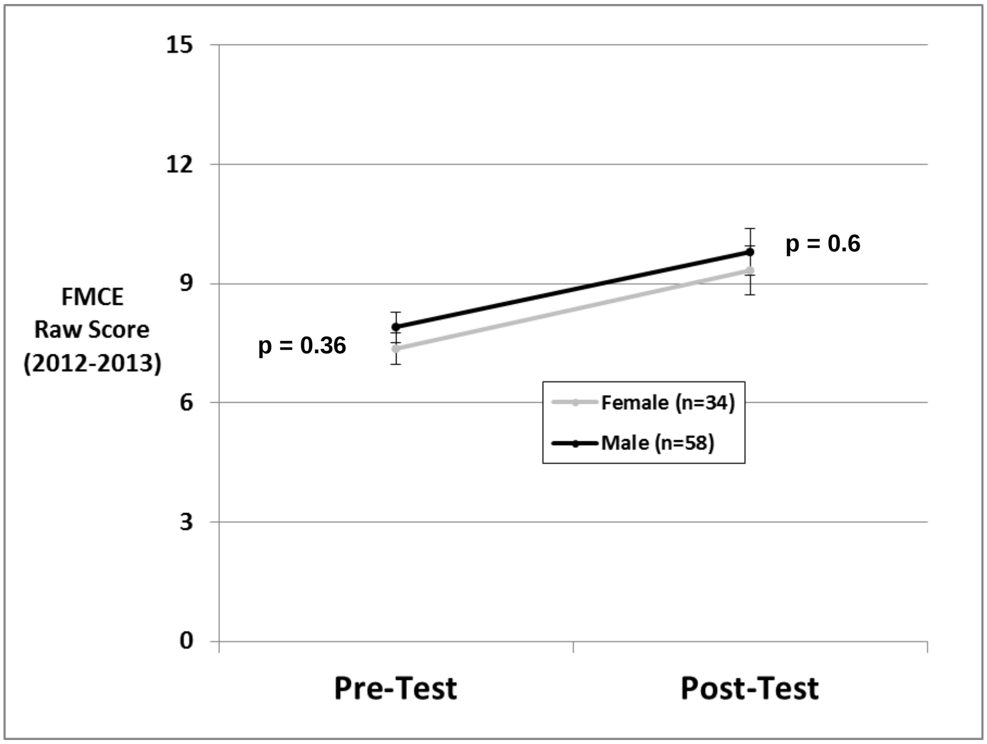

Figure 7: 2012-2013 General Physics Traditional Gender Comparison

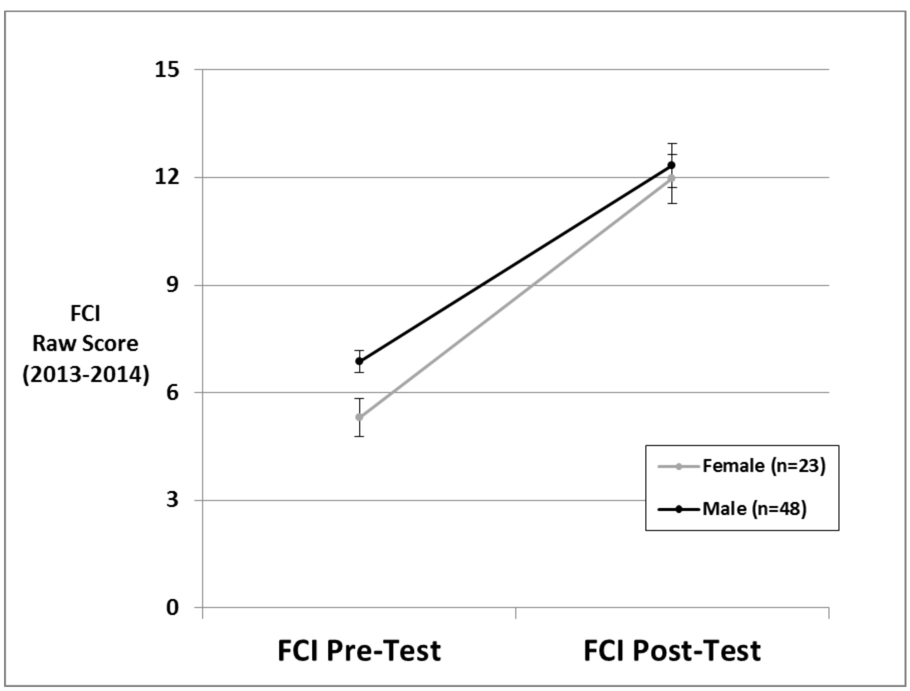

Figure 8: 2013-2014 General Physics Modeling Gender Comparison

In contrast, when analyzing gender data from the 2013-2014 academic year, the statistical analysis showed that there was a significant difference between female FCI pre-test scores and male FCI pre-test scores for the General Physics Modeling sample population, thus a significant “gender gap” was present prior to Modeling instruction. The FCI pre-test t-test resulted in a p = 0.008. A gender analysis of the FCI post-test scores was then conducted to determine whether the gap remained. The analysis showed that there was not a significant “gender gap” after Modeling instruction. The FCI post-test t-test resulted in a p-value=0.7. Modeling instruction appears to have impacted the “gender gap” that was originally present in this sample population, which is in line with other research.[13]

To determine whether male and female scientific reasoning skills could have factored into this result, a comparison was made between male and female CTSR pre-test scores and male and female CTSR post-test scores. This statistical analysis showed that there was no significant “gender gap” present in the CTSR either before or after Modeling instruction. It appears that the scientific reasoning ability of males and females was statistically similar before and after mechanics Modeling instruction.

It is necessary to take a closer look at other factors that could have affected the results of this study. To address the possibility of systematic errors in the experimental design and procedure, it is necessary to look at sample size. Since a couple of the groups in this study are of relatively small sample size (APB Modeling with n=12 and Traditional Female with n=15), it is irresponsible to draw more specific conclusions. In regard to pre-test and post-test incentives for students, the modeling instructor provided bonus points and the traditional instructor provided participation points to students for taking all pre-tests and post-tests administered. I believe most of my APB and General Physics students took the pre and post-tests seriously, with a few exceptions, and the other physics instructor made the same statement about his classes. I do not believe that the issue of students taking (or not taking) the diagnostic assessments seriously to be a significant factor in the outcome for the groups with relatively higher populations. However, the APC Traditional with an n=25 and a APB Modeling with an n=12 are small enough sample sizes that a few of the students not taking the pre-tests and/or post-tests seriously could possibly have had a significant effect on the results.

SUMMARY and CONCLUSIONS

With all data evidence considered, in addition to considering inherent issues with experimental design, the following conclusions can be reached. For the 2013-2014 academic year, all groups showed statistically significant increases in conceptual understanding of forces and motion as measured by the FCI whether taught by an experienced teacher using mostly traditional methods or taught by a novice modeler. Specifically, the FCI normalized gains among the four groups were all statistically similar, with the exception of isolating a comparison of the APB Modeling group and the General Modeling group. This difference could possibly be explained by the differences in scientific reasoning ability as measured by the CTSR and/or the difference in time between pre-test and post-test.

Although many studies show that using the Modeling methodology over Traditional instruction typically results in greater conceptual normalized gains, regardless of the instructor, I believe the experience level of the two individual instructors in this study was a significant factor. The Traditional instructor was an exceptional and experienced teacher who engaged the students with dynamic demonstrations, compelling lectures, many hands-on lab experiments, and effective problem-solving guidance. The Modeling instructor was a relatively new, alternatively certified teacher who enthusiastically navigated through the Mechanics Modeling curriculum with her students for the first time. The fact that the normalized conceptual gains were statistically similar between the two instructors could be attributed to the effectiveness of the Modeling methodology itself.

Furthermore, considering FCI pre-test scores, CTSR pre-test scores, and course schedule, the only two groups that were significantly different at the outset were the APC Traditional and the General Modeling sub-groups. In spite of this inherent difference, these two groups had statistically similar FCI normalized gains. This result also supports Modeling instruction over Traditional.

The most intriguing result in support of the Modeling methodology is the comparison of normalized gain on concept inventories for General Physics students taught traditionally in academic year 2012-2013 compared to General Physics students taught using the Modeling methodology in academic year 2013-2014. The FCI normalized gains of 25% $\pm$ <1.9% achieved by the General Modeling sub-group in 2013-2014 are significantly higher than the FMCE normalized gains of 5% ± <1.2% achieved by the General Traditional sub-group from 2012-2013. This is compelling evidence that the Modeling Workshop training and the utilization of the Modeling methodology had a positive impact on the General Physics student population.

In addition to the quantitative analysis and conclusions, I feel the need to share some of my qualitative experiences about both the Modeling Workshop, and the implementation of the modeling methodology for the first time. First, the Modeling Workshop was an extremely positive experience. The Workshop was taught by experienced high school modeling instructors (Master teachers), who took participants through the entire mechanics modeling curriculum in the same way that a modeling teacher is expected to instruct his/her students. At the end of the 3-week workshop at Arizona State, a majority of the instructional resources necessary to implement modeling effectively in the classroom were provided in printed and electronic formats to each participant. The network of other physics modeling instructors and the American Modeling Teachers Association (AMTA) website also proved to be invaluable and reliable resources throughout the implementation of the modeling framework for the first time. In summary, by attending a Modeling Workshop, a new teacher is certainly equipped with all of the instructional and network resources necessary to help him/her become an effective modeling instructor.

Even with specific Modeling Workshop training, the actual implementation of the modeling framework was a little more difficult than I anticipated. Some of the reasons for this struggle were not necessarily inherent to Modeling, but inherent to teaching in general. One of the challenges had to do with lab equipment and data analysis software. I found myself scrambling to acquire all of the equipment necessary to conduct some of the lab experiments recommended. As a novice teacher, I also struggled with how to use the equipment in the proper way. I do not have designated and updated classroom computers, so reserving a computer lab at applicable times within the Modeling cycle was also a challenge. Next year I will set up available laptops inside my classroom in order for students to use Microsoft Excel software when plotting and graphing experimental data. I could also use specific training on use of lab equipment, as this was not a focus in Modeling training.

Another challenge was the necessary adjustment to a more student-centered and seemingly "chaotic" classroom. With Modeling, the students regularly participated in group discussions while developing their models. Sometimes the discussions would veer off into social conversations that were irrelevant to the daily objective. Furthermore, classroom behavior often worsened when students were verbally challenged at "board meetings". It was uncomfortable for most students to be vulnerable while explaining their thought processes in front of their peers. Behavior did improve after a few months, but it was a struggle for a while.

I also had to find clever ways to administer remediation work for students who missed class time for various reasons. I did not issue a textbook with my Modeling classes, nor did I give much homework, so assigning supplemental reading or additional homework was not necessarily aligned with the Modeling framework. Next year I will utilize the online PhET[23] (Physics Education Technology) simulations, accompanied with an applicable printed structured inquiry activity, for students who miss valuable class time.

Another challenge with the classroom implementation of Modeling involved the facilitation of scientific discourse through Socratic questioning. I do not think I spent enough of my planning time preparing higher-level questions for the students, and I sometimes fumbled through the Socratic questioning portion of the Modeling method. I will hone those valuable questioning skills with more practice and experience.

After completing all mechanics units using the Modeling methodology, I did revert to a more traditional teaching style for other required topics such as fluids, thermodynamics, optics, sound, electricity/magnetism, and modern. I reverted to traditional instruction partially because I did not have the training and resources necessary to use the modeling methodology for those additional topics, and partially because I did not have the necessary preparation time to convert any of my traditional lessons to a Modeling framework. After reverting to traditional instruction, my students were visibly less engaged, and they commented about wanting to have "board meetings" again.

There were definitely times in the semester when I wanted to give up on Modeling because it was new, different and tough. However, now that I have analyzed the results of my data and experienced the different levels of student engagement using Modeling instruction compared to using Traditional instruction, I am more determined than ever to get back into my classroom and teach using the Modeling methodology. The results of my study support that Modeling tends to close the "gender gap" often seen in physics. The high level of discourse required in the Modeling method could be a factor in closing that gap. Furthermore, in spite of muddling through the Modeling curriculum as a new teacher and a novice modeler, and having a somewhat limited level of content knowledge, the Modeling methodology itself appeared to make up for that to a significant extent. My Modeling instructors encouraged all of us to take what we learned in Modeling training and tweak it to fit our own student population, our own personality, and our own school culture. That is what I intend to do.

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APPENDIX A
THE MODELING CYCLE

©Modeling Instruction – AMTA 2013 1 Overview v3.1

Modeling Instruction attempts to enhance student achievement through a process called the Modeling Cycle, following Robert Karplus's fine example, the Learning Cycle. Throughout the Modeling Cycle, we rely on student engagement and student explanation as the dynamic of learning. There are two major parts to the Modeling Cycle: *model development* and *model deployment*.

I. Model development

Every unit in our curriculum begins with a paradigm experiment that explores and develops the essential features of the model. Subtly guided by the teacher, students play a central role in designing the experimental procedure, collecting data, and analyzing and representing the patterns found in the data. Here is a typical approach to the paradigm experiments and their analyses:

A. Qualitative description. Students are shown the phenomenon to be modeled and the teacher elicits relevant descriptors from the students. In this brainstorming phase, the instructor non-judgmentally records each suggestion.

B. Identification of variables. From among the suggested descriptors, the instructor socratically guides students to identify those that may have a cause and effect relationship and can be measured. In this step, students distinguish the essential components of the model from the irrelevant details.

C. Planning the experiment. Once the purpose is clarified, the instructor presents the apparatus the students will use. Rather than hand out a lab procedure, the instructor guides a student discussion of possible ways to perform the experiment, recognizing that students will only understand their experiment if they have some say in the development of the procedure. The class breaks up into groups of three, ideally, in order to conduct their experiments.

D. Laboratory experiment. Using the apparatus provided, students make their measurements according to their procedure. Depending on availability use of data collection and analysis technology is encouraged. The instructor may encourage confused groups to use others as resources. Failure is allowed, as is the opportunity to repeat the experiment as needed.

E. Analysis of experiment. After collecting data, each lab group analyzes its data, often using computers, and seeks to make sense of the relationships between the variables of interest. A summary of their experiment and analysis is written on a whiteboard (24 by 32 inch segment of a 4 x 8 foot sheet of kitchen and bath tile).

F. Presentation of experimental results. Selected groups are called upon to present their findings to the rest of the class. Each group is expected to give a full account about what has been done and to express the relationships between the relevant variables in multiple ways (verbal, graphical and algebraic). The instructor questions the presenters as needed to elicit full explanations and to probe for any inconsistencies that have a bearing on their claims. Peer questioning is also encouraged and often is very fruitful. A coherent defense of the group's representations is the goal. Contradictory results among the laboratory groups are resolved by argumentation and discussion guided by the instructor. Groups that discover that they have made experimental blunders may return to the laboratory on their own time.

G. Generalization. The instructor helps the students reach closure by generalizing the particular relationships discerned by the students into theoretical statements. For example, after consensus has been attained among the students that the acceleration of a laboratory cart is directly proportional to the force that was applied to it and inversely proportional to its mass, a generalization to Newton's Second Law can be made. The instructor helps the students extract the structure and behavior of the relevant model from the details of the just-completed experiment, and to recognize that this model can be extended to a broader set of phenomena.

II. Model deployment

A. Extrapolation and reinforcement. Carefully selected and designed problems and activities allow students to determine how to deploy their models in a variety of contexts. These also allow students to confront common difficulties in the context of their experimental results.

Students work on these tasks in cooperative groups solving all the problems. The instructor asks members of selected groups to present the solution to given problems to the rest of the class. Presenters must explicitly articulate their solutions in terms of the models developed based on interpretations of experiments. During the presentation, students are encouraged to ask questions if they are uncertain about details of the solution or to offer suggestions that help, especially if the presenting group experiences difficulty. These class discussions are exceedingly valuable. Students are highly motivated to resolve their difficulties during the preparation of their solutions on the whiteboards so as to make competent presentations to their peers. They become more articulate in presenting and defending their points of view. When naïve conceptions arise, they can be addressed in the context of our models. During these presentations, the instructor assumes the role of "physics coach", guiding the students by asking probing questions to keep the dialog moving in a profitable direction.

B. Refinement and integration. Lecture demonstrations and counterexamples help the student refine the model, becoming aware of its limitations. Reading assignments from textbooks, film or video clips, aid in the integration of the model into its respective theory, bringing the cycle to closure. Student understanding developed earlier in the cycle provides an experiential and cognitive context that permits more meaningful use of these resources.

C. Lab practica. For many of the units, lab practica are provided. The lab practicum, as advocated by Jon Barber and Henry Ryan, serves as an excellent deployment activity for the application and reinforcement of the models and conceptual tools developed during the modeling cycle. The lab practicum involves giving students a laboratory-based problem. This lab problem should yield such clean results that students can be evaluated based upon their use of basic models to arrive at correct solutions. The lab practicum begins with the instructor posing a problem to the whole class as a group, and providing the laboratory equipment associated with the problem. The class is then required to work on the problem and to reach consensus as to the solution of the problem within a specified amount of time. They must then present and defend their solution in front of the teacher. As students defend their solution, the teacher may question any member of the class. The whole class either passes or fails the practicum based on whether or not their solution gives results that are within a reasonable range of the “correct” answer as predetermined by the instructor.

APPENDIX B
PHYSICS COURSE OFFERINGS HTHS 2013-2014

General Physics (220071)

Year-long / 1 credit
Grades 11-12

Recommended Prerequisite: Successful completion of Chemistry or Physical Science; current enrollment in Algebra II with Trig
Lab Fee Required

This course focuses on the core concepts of physics. The interactions of matter and energy are the foundations of the course. Computers and electronic probes are used extensively throughout the course to collect and analyze data. Laboratory investigations are used throughout the course to reinforce this core concept. Specific topics studied during the year include motion, forces, thermodynamics, sound, light, optics, electricity, magnetism, and nuclear physics.

AP Physics I/ AP Physics I Lab (220057)

Year-long / 2 credits
Grades 11-12

Recommended Prerequisite: Pre-calculus

AP Physics 1 is an algebra- based, introductory college-level physics course that explores topics of Newtonian mechanics (including rotational motion); work, energy, and power; mechanical waves and sound; and electrical circuits. Inquiry based learning and extensive laboratory experiments are used to help students develop scientific critical thinking and reasoning skills. The class prepares students for an end of course AP Physics exam to earn possible college credit for algebra-based AP physics.

Students who take AP classes will take the associated AP exam at the end of the course. The AP exam cost is $89 per exam and students are expected to take the exam for each AP course in which they are enrolled.

AP Physics C Mechanics (220075)

Year-long / 1 credit
Grade 12

Recommended Prerequisite: Successful completion of AP Physics I and teacher recommendation
Lab Fee Required

AP Physics C Mechanics is calculus based college physics course. It is designed to prepare students for the AP Physics C mechanics exam. A qualifying score (3 or better out of 5) on this exam is equivalent to 3 semester hours of calculus based physics credit at most colleges and universities. This course is extremely helpful for students interested in majoring in science or engineering. Physics C: Mechanics provides instruction in each of the following six content areas: Kinematics; Newton's laws of motion; work, energy and power; systems of particles and linear momentum; circular motion and rotation; and oscillations and gravitation.

Students who take AP classes will take the associated AP exam at the end of the course. The AP exam cost is $89 per exam and students are expected to take the exam for each AP course in which they are enrolled.

APPENDIX C
SAMPLE MODELING SEQUENCE AND UNIT

Physics Mechanics Modeling UNIT 2: Constant Velocity Model

1. Buggy Motion Lab

2. Reading: Motion Maps

3. Lab: Multiple Representations of Motion: Ultrasonic Motion Detector Lab; discuss lab

4. Worksheet 1: Motion Maps and Position vs. Time graphs

5. Worksheet 2: Motion Maps and Velocity vs. Time graphs

6. Quiz 1: Quantitative Motion maps

7. Constant Velocity Lab Practicum: Dueling Buggies

8. Worksheet 3: Position vs. time graphs and velocity vs. time graphs

9. Quiz 2: Average speed

10. Worksheet 4: Velocity vs. time graphs and displacement

11. Worksheet 5: Multiple representations of motion

12. Review Sheet

13. Constant Velocity Test

VITA

Melanie Matherne Dimler was born in Lockport, Louisiana in April 1974. She attended elementary, junior high school and high school in Lafourche Parish, Louisiana. She graduated from Central Lafourche High School in May 1992. The following August, she entered Louisiana State University Agricultural and Mechanical College, and she earned a Bachelor's degree in Mechanical Engineering in May 1998. After working in industry and then staying home with her children, she entered the Graduate School at Louisiana State University Agricultural and Mechanical College in June 2012 and is a candidate for a Master of Natural Science degree with a concentration in Physics. She is currently a high school teacher in *Trussville City Schools*, teaching Physics and Engineering at Hewitt-Trussville High School in Trussville, Alabama. Melanie can be contacted via email at *melanie.dimler@trussvillecityschools.com*.