2011

Occasional white boarding : examining the effects of physics students' understanding of motion graphs

Tony Schwaller
Michigan Technological University

Recommended Citation
Schwaller, Tony, "Occasional white boarding : examining the effects of physics students' understanding of motion graphs ", Master's report, Michigan Technological University, 2011.
https://doi.org/10.37099/mtu.dc.etds/535

Follow this and additional works at: https://digitalcommons.mtu.edu/etds
Part of the Science and Mathematics Education Commons

OCCASIONAL WHITE BOARDING: EXAMINING THE EFFECTS ON PHYSICS STUDENTS' UNDERSTANDING OF MOTION GRAPHS

By

Tony Schwaller

A REPORT

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

(APPLIED SCIENCE EDUCATION)

MICHIGAN TECHNOLOGICAL UNIVERSITY

2011

This report, "Occasional White Boarding: Examining the Effects on Physics Students' Understanding of Motion Graphs," is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN APPLIED SCIENCE EDUCATION.

Department of Cognitive and Learning Sciences

Signatures:

Report Advisor ____

Shari Stockero

Committee Member ____

John Jaszczak

Committee Member ____

John Irwin

Department Chair ____

Brad Baltensperger

Abstract

The Modeling method of teaching has demonstrated well-documented success in the improvement of student learning. The teacher/researcher in this study was introduced to Modeling through the use of a technique called White Boarding. Without formal training, the researcher began using the White Boarding technique for a limited number of laboratory experiences with his high school physics classes. The question that arose and was investigated in this study is “What specific aspects of the White Boarding process support student understanding?”

For the purposes of this study, the White Boarding process was broken down into three aspects – the Analysis of data through the use of Logger Pro software, the Preparation of White Boards, and the Presentations each group gave about their specific lab data. The lab used in this study, an Acceleration of Gravity Lab, was chosen because of the documented difficulties students experience in the graphing of motion. In the lab, students filmed a given motion, utilized Logger Pro software to analyze the motion, prepared a White Board that described the motion with position-time and velocity-time graphs, and then presented their findings to the rest of the class. The Presentation included a class discussion with minimal contribution from the teacher.

The three different aspects of the White Boarding experience – Analysis, Preparation, and Presentation – were compared through the use of student learning logs, video analysis of the Presentations, and follow-up interviews with participants. The information and observations gathered were used to determine the level of understanding of each participant during each phase of the lab. The researcher then

looked for improvement in the level of student understanding, the number of “aha” moments students had, and the students’ perceptions about which phase was most important to their learning.

The results suggest that while all three phases of the White Boarding experience play a part in the learning process for students, the Presentations provided the most significant changes. The implications for instruction are discussed.

Table of Contents

List of Tables

Chapter 1—Introduction

While attending the 2006 Wisconsin Society of Science Teachers (WSSC) Convention, I was introduced to *White Boarding* as a way of using the Modeling Method (Lattery, 2007) of teaching. As with the Modeling Method, the White Boarding technique is, at least in part, a creation of professors and graduate students at Arizona State University. In 2005, the University of Wisconsin at Oshkosh hosted a Summer Institute for high school teachers, emphasizing White Boarding as a method to teach secondary school Physics and Physical Science. It was three teachers from this institute who introduced the concept to me at the 2006 WSSC conference.

The Modeling Method of teaching promotes *starting* a unit or topic with a lab, rather than with teacher-led instruction, as is typically the case. In the case of a White Boarding lab, students typically complete the data collection on the first day. Students then spend multiple days analyzing the data and developing models to explain the phenomena under investigation. Each lab group presents their findings to the rest of the class using portable whiteboards. Each presentation is followed by a class discussion, led entirely by the students. The ultimate goal of this process is for *students* to develop the optimal model or formula that describes the phenomenon. At the end of the unit, the teacher may spend up to an entire class period reviewing what was learned and having the students use their newly discovered model/formula to answer standard word and lab problems. The teachers I spoke to when I first learned about this method suggested that each new topic takes about one week.

Notice that the Modeling Method seems to turn the traditional teaching method nearly backwards. Instead of the teacher providing the model or formula, then asking students to use the concept, and finally, having them complete a seemingly mandatory confirmation lab, the students begin with the lab, and *develop* the model *for themselves*. Once developed, they use the model to solve traditional word problems and perform other labs.

Notice also that the amount of time necessary to engage students in this type of learning is immense. It takes one week to complete a single concept. One of the teachers I spoke with completes less than half of the material that I cover in a typical school year. However, he remains adamant about his results.

Previous Use of White Boarding

In thinking about my own classroom instruction, I was both impressed and intimidated by the concept of teaching with the Modeling Method. The method is sometimes broken down further into the concepts of *Socratic modeling* and *modeling discourse*. In simplest terms, it may be argued that it is just another form of teaching with inquiry. These are all proven teaching methods and, some would argue, the ideal methods of teaching science in schools. As effective as these methods are, they do, unfortunately, consume large amounts of valuable classroom time. To this end, these methods do not seem to be a practical approach for daily teaching if one expects to meet the standards set by the State of Michigan High School Course Content Expectations (MDE, 2006).

Immediately upon returning from that 2006 WSST Conference, I was fired up, and ready to try White Boarding in my own classroom. In Physical Science, the very challenging Graphing Phase Changes Lab was looming. The great challenge with Graphing Phase Changes, at least for freshmen, is the concept of *why* temperature does not go up while ice is melting, and *why* it does not go up once water has reached a boil. For years, I *explained* the concepts of Heat of Fusion and Heat of Vaporization to students, showed them beautiful graphs, and expected them to understand. I even had them do their own lab, starting with ice water, heating it and recording the temperatures every thirty seconds until the water was at a full rolling boil for three minutes. Students would then graph the results to verify everything we covered in class. It was all perfectly logical. But the students did not grasp the concept. I knew that the way I taught this particular concept was ineffective, and needed to change. It seemed like an opportunity to put White Boarding to the test.

I rewrote the lab, eager to kick the tires on this new technique I had just been introduced to. For a first try at a new lab method, I was pleased. Of course there were things that needed to be changed, from minor tweaking to major revising, but one moment from that lab stood out in my mind and had me hooked on the concept of White Boarding. During the discussions of each group's graph, the question always arose, "Why did the temperature not increase at certain times?" Students made valiant efforts at answering, but they did not have a good answer for the question. Until, that is, one student proffered that perhaps "the energy is going into melting the ice" causing the phase change, and *not* into raising the temperature of the water. When I heard

those magic words, coming from a student, I could not contain my joy. This particular student explained the concept to the rest of the class, and slowly, the room got brighter and brighter as lights went on in most students' heads.

I had similar experiences in each of my classes, and based on informal questioning, casual observation, and test scores, it was obvious to me that students learned the concepts better than they had from my previous efforts.

The Study

Now that I had a taste of the White Boarding technique, I wanted to use it more often. I did, indeed, ponder switching to the full time method that my colleagues who had introduced me to the technique promoted. However, I simply could not get my mind around teaching this way full time. I also knew I could never come close to covering the material the state expects me to cover. So I settled on choosing a few labs, identified by the concepts that seemed to me to be the most difficult for students to grasp, for which to use White Boarding.

In Physics, this meant the Acceleration of Gravity Lab, a seemingly valuable part of my teaching toolkit since I first began teaching. On the surface, this should be an easy concept—it's gravity, duh! But my experience suggested that students just went through the motions during the lab because, after all, it *is* just gravity. They already knew the value for the acceleration of gravity on earth is 9.8 m/s^2; what is there to discuss?

When I first used this type of lab, it involved Dot-Timers or "ticky machines", the clunky devices that utilized a motor, carbon paper and a roll of ticker tape. Students

would drop an object connected to the ticker tape, use a meter stick to compile position-time data of the object, then turn that into position-time and velocity-time graphs all to determine the acceleration of gravity, hopefully to within +/- 10% of accepted. They were never surprised by the findings. More importantly, they never gave much thought to the process. I wanted them to use this lab to reinforce the concept of gravity, while also strengthening their graphical analysis skills. The way I was doing this lab seemed to be ineffective at both. Well, we've come a long way baby.

The first improvement to the lab came when I discovered and began using Logger Pro software (Vernier, 2011). Logger Pro replaces the Dot-timers, the tedious measurements and hand-graphing with video footage of the motion. Using the software, one can track the motion of an object in the video, frame by frame. If a meter stick is in the footage to provide a scale, the software will develop the data tables and graphs for the student. The program even allows for a quick analysis of slope, tangent lines, and other useful data. While it took multiple rounds of revisions and rethinking in order to have enough light for the camera images to be sharp enough to use and to learn how to properly utilize this new tool, it provided a distinct improvement over the Dot-timers.

After my first White Boarding experience, I completely revamped the Acceleration of Gravity Lab once again. My goal was to create a more comprehensive lab, emphasizing the graphical analysis, and, of course, turning it into a White Boarding experience. Because the students would be presenting their results to the class, I strove to create multiple different situations, all with the same theme of graphing motion and

interpreting the graphs, but different enough to keep each presentation fresh. I immediately had positive feedback from the students, as well as some indication of improved understanding of the graphing concepts. Over the course of a few years, I fiddled with the lab, making small changes here and there.

I have continued to be intrigued by the White Boarding process, but having not been formally trained in the technique, and not being willing to sacrifice the amount of class time the method requires, I have opted to use White Boarding on a limited basis in my classroom. In freshman Physical Science, I employed the technique for five labs during the 2009-10 school year. In senior Physics, I utilized it for three labs. In my altered version of White Boarding, my students and I typically have touched on a subject in a class discussion before student exploration, but have not gone into great detail. There are plenty of “unexplained” concepts that await student self-discovery. The Modeling Method places great emphasis on student discourse in both small groups and full class settings in order for the concepts to be discovered. Since my students are not “trained” throughout the school year to use this method, it involves a distinctly different way of thinking than students are accustomed. As expected, these labs take significantly more class time than the standard “canned labs” they replace. They also have led to some intriguing results.

When it came time to pick a topic for my MS-ASE capstone project, White Boarding seemed a good topic. I initially wanted to prove that this technique is more effective than the traditional method of teaching labs, even when used on a limited basis such as I was doing. However, I was unwilling to “sacrifice” a group of students to

the traditional method to act as a control group. Besides, at the start of this project, I already felt intuitively confident that students learned better using the White Boarding method, especially with some particularly difficult concepts. What I did not know, however, was how White Boarding helps students learn. While this was too broad of a topic, it did highlight a lingering question in my mind: What specific aspects of the White Boarding process support student understanding? Is it the data collection and graphical analysis aspect of the lab? Is it the preparation of the White Board? Or is it the presentation and discussion that goes along with the lab? It is these questions that this project seeks to answer.

Chapter 2 - Literature Review

Graphing Motion

The graphing of motion is a common stumbling block for students. McDermott, Rosenquist and van Zee (1987) found that even college level physics students have difficulties with graphing that are NOT related to knowledge or preparation in mathematics. Students can plot a graph and compute slopes, but they cannot apply their knowledge to physics and real-life situations. Barclay (1985) supports this conclusion, finding that students have a tendency to view a graph as a picture. For example, a biker rides up and over a hill, coming back down to the original elevation. The position-time graph will look strikingly similar to a "picture" of the motion, as viewed from the side. However, students fail to understand that the horizontal axis is time, and not horizontal position. Moreover, they have the tendency to confuse the velocity-time graph of the same motion with the position-time graph.

Yet other studies have identified specific difficulties that students have with graphing motion. A common theme is the difficulty in finding the connections between motion graphs, physics concepts, and the real world. Again, these studies add support to the idea that students often view graphs as just a picture (Linn, Layman, & Nachmias, 1987; McDermott, Rosenquist, & van Zee, 1987; Svec, 1995). Svec (1995) also found that students have trouble in determining the direction of graphs, and commonly confuse the types of graphs.

The apparent explanation for these graphing difficulties is what appears to be a common problem in teaching high school science. Students come into the classroom with strong preconceptions (typically *mis*conceptions) about physics that are “highly resistant to change” (Clement, 1982, p.70). Moreover, these common misconceptions, such as those discussed above, are difficult to replace with accepted scientific beliefs because the misconceptions are from a lifetime of experience (Halloun & Hestenes, 1985a). The use of the Force Concept Inventory (FCI) has since shown how difficult it is to replace these misconceptions with the accepted Newtonian concepts (Hestenes, Wells, & Swackhamer, 1992).

Compounding the problem for a classroom teacher is the common sentiment among science education researchers about the importance of understanding motions graphs. If a student is to effectively learn about motion, he or she must do more than simply use equations and know the vocabulary. According to Arons (1990), motion graphs, used in conjunction with verbal and mathematical descriptions, make a valuable contribution to the understanding of position, velocity and acceleration. Supporting this notion, McDermott, Rosenquist & van Zee (1987), argue that graphing, understanding, and interpreting graphs is perhaps the most important skill that students can learn in an introductory physics class. They go on to state, “For students taking physics, either in high school or college, an ability to work with graphs is likely to be more useful in future academic work than knowledge acquired about any specific topic” (p. 513). Those are strong words, but thankfully, research also provides insight as to how to go about teaching students about the graphing of motion more effectively.

Among the research findings is that the teaching of graphing must provide plenty of practice with graphing, including in laboratory settings (Svec, 1995), require the learner to actively think about the meaning of the graph or graphs and how it relates to the motion of the object (Arons, 1990), and provide concrete, direct experience of the motion that is being graphed (Nemirovsky, Tierney, & Wright, 1997). Additionally, Svec tells us that students must make both position-time and velocity-time graphs of the same motion, to compare and contrast the two. The good news here is that the Graphing Motion Lab in this study employs each of these strategies.

Socratic Method

Successful schools require students to, among other things, use knowledge and skills in solving real-world problems, share what they have learned with others, and work with other students to complete challenging math and science assignments. "Student-centered learning is based on the belief that active involvement by students increases learning and motivation" (Tanner, Bottoms, Feagin, & Bearman, 2003, p. 8).

This idea of "active involvement" is a reemphasis of what has already been stated with regard to improving the learning of graphing. In addition to the active involvement of the students' minds by immersion in the motion and in the graphing process, active involvement by working with other students is likewise important. Cooperative and collaborative learning are valuable skills in real life, which are not emphasized enough in the traditional classroom. Without these types of experiences, students would "miss the opportunity to learn with and from their peers" (Tanner et al., 2003, p. 8).

One type of student-centered instruction is using the Socratic Method. More than just cooperative learning, the Socratic Method of teaching involves modeling the behavior of Socrates, by posing to students questions that require thoughtful responses. As Tanner et al. (2003) clearly state, "The greatest challenge is to design thought-provoking questions that will engage students in productive discussions" (p. 14). The teacher plays the role of inquisitor, searching for knowledge from the students by asking follow-up questions that lead the students to defend their positions and explain their thinking. "When teachers use questions to probe student thinking, they help students process information into meaningful terms and reach a deeper awareness of the issues" (Tanner et al., 2003, p. 14).

While the probing Socratic questions are typically posed by the teacher, the Modeling Method provides a classroom full of peers to act the part of Socrates. A requirement for Socratic discussions is to place the ownership for learning with the students. Again, this fits perfectly with the Modeling Method, as well as with the modified White Board Labs.

When it comes to Socratic discussions, the teacher must be on the sidelines, with the majority of the discussion coming from the students. Indeed, the students need to *know* that the teacher will not save them by contributing to the discussion. Again, this fits very nicely with the Modeling Method, though I must admit to failure in my White Board Labs. Perhaps due to the infrequent use of these labs, perhaps due to my inexperience and lack of training, or perhaps for still other reasons, I end up interjecting in the discussions with some frequency. This is breaking the rules of a Socratic Seminar,

according to Ball and Brewer (2000), who state that strictly speaking, the teacher should become nothing more than a “manager”. They go so far as to state that teachers should not communicate that they agree or disagree with anything being said, even with facial expressions.

Modeling Method

In 1983, Arizona physics teacher Malcolm Wells was looking to improve his classroom instruction. By all accounts, Wells was already an amazing teacher, who constantly strove for improvement in his classroom. Most recently, he had been using a student-centered inquiry approach. However, after testing his students with the Mechanics Diagnostic (Halloun & Hestenes, 1985b), Wells found that his students were doing no better than students taught in a traditional classroom. The Mechanics Diagnostic, a precursor to the FCI, tested student perceptions and misconceptions of Newtonian concepts (Wells, Hestenes, & Swackhamer, 1995). At the same time, David Hestenes of Arizona State University (ASU) was formulating a method of teaching using modeling as the central theme (Hestenes, 1987). The original purpose of the Modeling method Hestenes was developing was two-fold. The primary objective was for students to have a more genuine scientific experience, emulating how real physicists and scientists work. A second objective was to address the "serious weaknesses in traditional instruction" (Wells, Hestenes, & Swackhamer, 1995, p. 4). Wells tweaked the Modeling Method by adding the White Board component, which was an easy to use instrument that allowed for improved student discourse. After fully incorporating the Modeling Method in his classroom, Wells set about testing his results. He found that in

comparison to his previous inquiry approach, as well as to a comparable traditional classroom, students from his modeling method class scored significantly higher on both the FCI and the Mechanics Diagnostic. Further research found that his Modeling students had very similar scores to students enrolled in University Physics at Harvard, and even to first year physics graduate students at ASU (Wells, Hestenes, & Swackhamer, 1995).

Wells went on to earn his doctorate at ASU, with Hestenes as his advisor. That partnership continued, with Wells adding the genius of using simple white boards for students to relay concepts, show graphical trends, and present their models. The concept of White Boarding was born. Modeling requires students to discuss "how they know what they know" (Blanton, 2008, p. 188). The white board is a practical and simple way to encourage this discourse. This method, combined with Wells' ability to use Socratic questioning, led to his students to finally demonstrate understanding of Newtonian concepts, as measured by the Mechanics Diagnostic and later the FCI (Wells, Hestenes, & Swackhamer, 1995).

Gregg Swackhamer of Glenbrook North High School in Illinois had the pleasure of working with and observing Wells in his natural habitat, the classroom. He related that the moral of Wells' method is clear: We cannot expect students to learn effectively by having an expert in the field (the teacher) *tell* them how the natural world works. Knowing that students will construct their own understanding, he sought to guide them to the scientifically accepted views by acting as a facilitator. He sought life-long

understanding, and strove not to teach *what* to think, but *how* to think (Wells, Hestenes, & Swackhamer, 1995).

According to Hestenes (2006), the biggest problem with traditional instruction is that it refuses to even acknowledge the "common sense" beliefs that students bring with them to the classroom. In contrast to that, the Modeling Method is specifically designed to attack these misconceptions by having students develop their own models and explanations for their observations of the world. The discourse that follows, based on the models students have developed, encourages students to elaborate on their explanations, and compare them to Newtonian models. Also helping with the process are the graphs and equations used to simplify and clarify those models. Instructors become well-versed in the misconceptions that students bring with them, and help the students find the discrepancies in their conceptions, and resolve the issues on their own. As Hestenes (2006) has pointed out, and many others know well, "Telling them answers does not work" (p. 18).

Modeling has proven to be a highly effective means of physics instruction. In one study, students who were taught using traditional methods were compared to students taught by the same teachers using the Modeling Method. Students taught by teachers using Modeling, even those teachers considered to be novices in the discipline, scored significantly better on the FCI. Students of teachers considered expert Modelers showed more than twice the improvement than their traditionally-instructed counterparts (Jackson, Dukerich, & Hestenes, 2008).

A Word of Caution

Henderson and Dancy (2009) took a closer look at teachers who have a basic awareness and knowledge of Research-Based Instructional Strategies (RBIS), but who have not been formally trained in the complexities and nuances of the strategy. Included in the 24 RBIS that are applicable to physics was the Modeling Method. The study found that modification of the implementation of RBIS is common practice among teachers, although with the given survey data no conclusions could be drawn about the impact of these modifications. They did, however, find that a disproportionate number of participating teachers discontinued the use of the particular RBIS program they had implemented. The implication is that teachers who have not been trained in a given RBIS and who are not thoroughly versed in the implementation of the system may not have the skills to adapt the system to their particular situation. For me, this is an alarm; my formal training in the Modeling Method involved a three-hour workshop at a teacher conference. My follow-up training involved emailing my cousin (one of the original presenters at the WSST conference) and visiting another presenter's classroom (at my high school alma mater) for an hour of discussion and observation. Beyond that, I have read literature. In other words, I am absolutely what Henderson and Dancy would consider at-risk to discontinue the use of the Modeling Method, for lack of knowledge and appropriate training. I am comforted by knowing that, if anything, I am excited to learn more about the Modeling Method, rather than discontinue its use. Still, the concern that I am straying too far from the intended purpose of the Modeling Method remains prominently in the back of my mind.

Chapter 3 - Methodology

Participants

The students who participated in the study were enrolled in two sections of Physics taught at Houghton High School in autumn of 2010. Prior to the start of the study, all of the students were informed of their rights as human subjects and both they and their parents were given the opportunity to sign an informed consent form if they agreed to participate (MTU IRB protocol M0640; see Appendix A for IRB approval form and participant consent letters). Of the 49 students enrolled in the two classes, 48 agreed to participate in the study. Of these students, 44 were seniors, 3 were juniors, and 1 was a sophomore. The gender ratio was very nearly even, with 23 male and 25 female students participating. It should also be noted that Physics at Houghton High School is an elective class, with Algebra II preferred as a pre-requisite, but accepted as at least a co-requisite for seniors who express a strong interest in the class.

The Lab

For the White Boarding lab, students were randomly broken into groups of three, with each group given a specific acceleration situation to film with a digital camera. While no two groups' assignments were exactly the same, they shared the common goal of analyzing and interpreting the resulting motion graphs. The specific tasks involved the filming of the motion of:

1. A neodymium magnet as it passed through a Cu tube
2. A wind-up car that first accelerated up to speed, then slowed to a stop

3. A golf ball as it bounced three times on a counter top
4. A kickball as it bounced three times on the ground
5. A Styrofoam plate falling vertically along a fishing line
6. Two discs of identical mass and diameter, one solid and one hollow, rolling down a ramp
7. A cart on an inclined air-track, while it went through 3 bounce cycles
8. A cart on an inclined air-track, attached to the top of the track by a spring, for 3 rise/fall cycles

One entire class period was dedicated to the filming of these scenes. The students were careful to film from a position perpendicular to the motion, and from as far away as possible, while zooming in to have the motion take up as much of the screen as possible. Each group also made sure to have a meter stick within the screen, at exactly the same depth as the motion being filmed. Lights were brought in from the video production class in order to increase the camera shutter speed and thus improve the quality of the images.

In the second class period, students examined their films utilizing the Logger Pro software. Each student used the software independently, and then the group members compared their results with each other. The resulting graphs that were the “smoothest” were chosen by the groups for the data analysis. The smoothest graph was simply a function of the best eye and best placement of the cursor when setting the points for each data point, or even the clearest video depicting the motion.

Very quickly, the students created displacement and velocity graphs of their motion. It was now time for them to interpret the meaning of these graphs. As discussed earlier, students traditionally have great trouble with motion graphs in high school (Barclay, 1985; Linn, Layman, & Nachmias, 1987; McDermott, Rosenquist, & van Zee, 1987; Svec, 1995). The "bounces", in particular, seemed to be a stumbling point for many of the students. While some class time had already been dedicated to covering the meaning of these graphs, students were still challenged by interpreting their results.

Each group was directed to interpret their results, and to prepare a White Board on which they would present their lab results to the rest of the class. Specifically, students were instructed to develop a presentation in which they would explain the motion of their object, and how that motion related to the position and velocity graphs they had developed. The presentation was to use White Boards as a medium. The students were already familiar with the basics of White Board presentations from earlier science classes at the school. A common theme in class is that "every graph tells a story"; for the purposes of this presentation, the students' job was to explain that story to the rest of the class. Most of the third class period was devoted to preparing the White Boards, though there was enough time at the end of the hour to do one presentation in each class. The entire class on the fourth day, and the first fifteen minutes of the fifth day were dedicated to presentations.

The teacher's role during the presentations was to sit back as much as possible and observe. Students were encouraged to ask questions of each set of presenters, and to dig into the meaning of each group's graphs. At times, when it was felt that the class

was struggling too much, or going irretrievably in the wrong direction, the teacher intervened to help clarify. During each intervention, the teacher corrected the difficulty and stepped back out of the way as quickly as he could.

Data Collection and Analysis

A video camera was running the entire time during the White Board presentations, viewing not only the presenters, but the students in class as well. Students also kept a Learning Log each day, recounting what they felt they had learned and when in the process they perceived that learning had occurred. The Learning Log was meant for the student to reflect on what had been learned and specifically when and where learning took place.

After reviewing the Learning Logs, the researcher conducted recorded interviews with select students. To ensure that a range of students were represented, students were strategically selected for interviews based on information in the Learning Logs and classroom observations. Approximately 45% (22 students) of the study participants were interviewed. The interviews attempted to dig even deeper into the learning process, and to help students identify when and where (and perhaps if) learning had occurred during the lab process. To gather this information, the following interview questions were used:

- What part of the White Boarding process did you feel helped you to learn the most?
- What about this process helped you to learn?

- Do you feel you would have learned as much if you had completed the lab and turned in a written report, instead of doing a presentation? Please explain.
- Do you feel you would have learned as much if instead of student presentations, the teacher had led a class discussion about situations encountered in the lab? Please explain.
- Do you have any other comments you would like to add about your white boarding lab experience, especially as compared to a traditional lab?

Specifically, the researcher tried to gather evidence of students' learning at three points in the process: during the Logger Pro data analysis, during White Board preparation, and during the small group discussion, as either a presenter or an audience member.

The data analysis focused on documenting evidence of students' level of understanding. At times during the presentations, some students would spontaneously blurt out that they "got it". Students also declared in their Learning Logs that they understood what was going on, but did not always include evidence to support the claim. While statements claiming understanding were helpful, it was not enough to go on. Instead, concrete evidence of learning was looked for, such as a student correctly restating a concept or applying a concept.

Sadly, students do not literally have light bulbs atop their heads that light up when learning occurs. In lieu of that obvious indication of learning, the researcher read the Learning Logs and watched the presentation videos to look for indications of

learning. For each step of the White Board process, each student was designated in one of three categories based on their understanding of the concepts: Simple, Emergent, or Deep. These designations were assigned based on the following criteria.

Simple:

- Understands that graphs are not “pictures” of the motion
- Understands the significance of slope of each graph, but is not able to use that information to explain the motion being observed
- Have basic knowledge of graphs, but may state that they are “confused”

Emergent:

- Can use the slope of v-t graph to determine acceleration, and relate this to what the object is doing at that time
- Understands the significance of the curve crossing the axis on each graph
- Understands the significance of the curving being above and below the axis on each graph
- Can see the motion, and see the graphs, and agree that they go together, and even spot problems with some graphs, but has difficulty in generating/predicting the graph of motion on their own
- Has difficulties with the differences between horizontal and vertical motion graphs for 2D motion
- States that they don’t have a full grasp of the information

Deep:

- Understands relationships between d-t and v-t graphs, and can predict one from the other
- Understands and can predict differences in horizontal motion graphs and vertical motion graphs for an object moving in 2D
- Can explain and relate the motion of an object to the graphs of that motion
- Can predict the graphs for any given motion with little or no difficulty

In addition to the student Learning Logs and the presentation footage, the interviews were used as additional evidence of student learning in order to triangulate the coding.

During the coding process, it was found that two additional categories were needed for the classification of students: Confused, for a student who was not yet to the Simple standard, and Unclassified for students who did not provide enough information to be classified, or who were absent for one particular phase. This designation was most common during the White Board preparation phase, as many students did not address this aspect of the lab in their Learning Logs. When the coding was complete, the number of occurrences of each type of understanding was compared for each of the phases of the White Board process.

After determining the number of occurrences of each classification of understanding in each phase, the number of students who advanced one level of understanding during each phase was noted, as were the number of students who had one or more “aha” moments during each phase. Additionally, the student interviews

provided unexpected insights about the White Boarding experience. These insights will be discussed in the results section.

Chapter 4 – Results

The working hypothesis going into this study was that all three aspects of the White Boarding process—Analysis of Data, the White Board Preparation, and the Presentations themselves—would support student learning. Furthermore, it was hypothesized that the occurrences of learning in each phase would be relatively equal to each other.

After collecting all of the data, twenty-eight students provided enough information in their learning logs to be useful for the data analysis. The learning logs, though helpful to the researcher, were not as complete as had been hoped. There were also several planned methods of data collection that unexpectedly failed, or were of little to no value to the researcher. However, the quality of the early interviews led the researcher to interview twenty-two students, as opposed to the proposed five to ten students. Ultimately, the interviews not only helped to confirm the results of the learning logs and classroom video, but also led to some interesting insights of their own.

The combination of learning logs, video analysis of presentations, and interview questions provided evidence regarding the level of understanding that each student was at during the various phases of the lab, as well as the advancement of understanding during any given phase. The data analysis also provided insight as to the number of students experiencing at least one “aha” moment during a particular phase of the lab. The interviews then provided insight as to which phase each student felt was the most significant to his or her learning, as well as what the students thought about various

potential modifications to the lab process. The details of what was learned through the data analysis are discussed in the following sections.

Level of Understanding

Table 1 summarizes the occurrence of each level of understanding during each phase of the lab.

Table 1

Number of Students at each Level of Understanding During the Various Phases of the Lab

	Confused	Simple	Emergent	Deep	Unclassified
Analysis of Data (with Logger Pro)	1	5	11	7	4
Preparation (of White Boards)	0	3	13	6	6
Presentations	0	1	11	16	0

The first thing to notice in this data is the number of students with the designation of Confused or Simple. At the Analysis phase, there were six students within these two categories combined. By the end of the Presentations, only one student remained in the Simple designation. It should be noted that this student was Unclassified during the Analysis phase, indicating that all six students who began in the Confused or Simple categories had improved to at least an Emergent classification by the end of the lab.

The number of students who were designated as Deep saw a significant leap during the Presentations portion of the lab. There did not appear to be an improvement in the number of students classified as Deep during the Preparation phase. This was

difficult to determine, however, as six students did not present enough evidence to be classified for that portion of the lab.

Advancement of Understanding

Table 2 summarizes the occurrences of level advancement and number of "aha" moments for each phase of the lab, as well as student declarations of the "most important" phase of the lab.

Table 2

Value of Various Phases of the Lab as Measured by Several Different Indices

	Analysis	Preparation	Presentation
Number of students who advanced from Confused to Simple	Not applicable	1	0
Number of students who advanced from Simple to Emergent	Not applicable	4	2
Number of students who advanced from Emergent to Deep	Not applicable	0	9
Number of students who experienced one or more "aha" moments during phase	5	5	18
Number of students who expressed in the interview that this was the "most important" aspect of the lab for them	3	6	13

Next, the advancement of understanding from one level to another will be considered. Because the level of understanding each student entered the lab with was not known, it was impossible to determine if there was improvement during the Analysis phase. This phase will be assessed with other methods of analysis. For now, let us look strictly at improvement from one level to another during the Preparation and Presentation phases. As shown in Table 2, five students improved one designation level

of understanding during the Preparation phase, while eleven students demonstrated one designation level improvement during the Presentation phase. Of the five who improved during the Preparation phase, four of them increased from Simple to Emergent, while the other student improved from Confused to Simple. Contrast that to the eleven students who improved during the Presentation phase; nine of those students improved to Deep understanding, while two improved to Emergent. It appeared from this analysis that the Preparation phase may have provided more opportunities to improve for the students with lower levels of understanding, whereas the Presentations appeared better to help students make the leap to Deep understanding.

This does not suggest, however, that the Analysis and Preparation phases were not useful to students who were already at Emergent or Deep understanding. For example, Isabel, a student who was Emergent during the first two phases, said of the Analysis phase "It really helped me understand the graphs when [Logger Pro] would show them as you went. Helped a ton!" Another Emergent student, Nora, echoed that sentiment by writing that it was "useful for me to see what was happening on the v-t and the d-t graph relative to each other." Perhaps the best summation of the Analysis phase was provided by Deep understanding student Steve, who wrote "Although I understand the velocity/graph/acceleration stuff fairly well already, it was still beneficial to do this, even if it is a review of some sort." The typical student assessments of the Analysis phase ranged from it being a good review and reinforcement, to it providing an

"aha" moment. The most negative comments were along the lines that it was "not helpful, because I knew all this already."

Student comments about the Preparation phase had two common themes: small group discussion and peer pressure. Two Emergent students, Xena and Yana, both appreciated the Preparation phase because of the small group discussion and explanations provided by their partners in this phase. The students indicated that the more individualized attention helped them to resolve their difficulties easier than in the larger full class Presentations. More prevalent was the sentiment that Doug gave when he said that in the Preparation phase students "have to understand concepts to explain to [the] class." Nora's comment supported this, as she stated that Preparation helped because "if we're going to go in front of the class, we need to know what we're talking about." This led students to think each situation through more thoroughly. While it was evident that the peer-pressure aspect of the presentations played a role in motivation, it is not apparent that this directly led to a better understanding of the material.

"Aha" Moments

A focus of the learning logs was to record "aha" moments when they occurred. Table 2 summarizes these moments. There turned out to be five students who had one of these moments during the Analysis phase, and five who had an "aha" moment during the Preparation phase. On the surface, these numbers pale in comparison to the eighteen different students who had one or more "aha" moment during the Presentation phase of the lab. It should be noted that the Analysis phase was approximately one class period, the Preparation phase was less than one full class

period, and the Presentation phase was two full class periods, as well as approximately ten minutes of two other class periods. While the significantly larger amount of time devoted to the Presentations cannot be overlooked, it does appear that this phase had the largest impact on student learning, or at the very least was associated with the largest number of “aha” moments.

One particular “aha” moment, documented in Lenny’s learning log, specifically addressed the “graph as a picture” misconception discussed in the research (Barclay, 1985; Linn, Layman, & Nachmias, 1987; McDermott, Rosenquist, & van Zee, 1987; Svec, 1995). Lenny wrote, “I had an ‘AHA!’ moment when he explained that even if a ball was bounced straight up and down, it would still have a graph shaped like [a picture of a bouncing ball] because the graph is only showing the distance traveled from the ground, not the motion of the ball.” It should be noted that the “he” referred to in this log entry is not clear. While it is possible that it refers to the teacher stepping in to clarify, it is also possible that “he” refers to a student presenter. Unfortunately, the video segment of this exchange was cut off when the video recorder ran out of tape moments before the exchange in question.

Another “aha” moment was shared in the learning log of Vince, as he wrote about his learning during the Preparation stage. “During our work, I realized that the inflection point [on the position-time graph] corresponded with the corner of the velocity-time graph.” This supports Svec’s (1995) claim that it is useful to compare position-time and velocity-time graphs of the same motion.

Students' Opinions about the White Boarding Process

Most Important Phase

Each interview began with the researcher identifying the three phases of the lab for the student. The student was then asked "Which phase of the White Boarding process was most important to you?" While all three phases of the process were represented, and multiple students expressed that they were all valuable, the Presentation phase again emerged as the most common response. The Analysis phase was considered most important by three of the students, Preparation by six students, and the Presentation phase by thirteen of the twenty-two students interviewed. These results are also summarized in Table 2.

Students were then asked to explain their choice. All three students who expressed that Analyzing was the most important phase said it was because the Logger Pro software allowed the student to "see" the relationships between the motion and the graphs. Interestingly, two of these students were identified as being at Deep understanding for the entirety of the lab, while the third was identified as Emergent throughout the lab. This is a bit of a surprise when compared to the earlier observation that the Preparation phase might be most important to students at the lower levels of understanding. Based on the previous analysis, one might have been tempted to conclude that during the Analysis phase of the lab, it was the lower level students' understanding that was being most addressed. Having two students with Deep understanding tell the researcher that Data Analysis was the most important aspect of the lab for them was indeed a surprise.

Among the students who found the Preparation phase to be the most important, familiar themes emerged. Michelle stated what Xena and Yana also re-expressed during the interview, that the “small group discussion was helpful.” If the discussion was important, why then would the presentation phase not be most important? Michelle answered that question by stating that “People catching on too quick” hurt that aspect of the lab for her. For all three of these students, the emphasis on *small* group discussion and the more personal interaction between students that occurred in small groups appeared to be most helpful. The three other students who claimed Preparation to be most important did so based on the “pressure” they felt in “trying to understand enough to explain to others” (Vanessa).

There were numerous explanations given by students for choosing the Presentations as most important to them. A comment heard several times focused on the importance of seeing and hearing about other students’ motions, and the accompanying explanations and strategies employed in deciphering the motion graphs. While multiple students expressed that the *different* motions were helpful, as there was a need to “think critically” (Dave) about the different situations, another student, Nora, noted that the *similarities* between other groups and her own group “made it click in my head.” Yet another student, Rose, stated that the presenting provided reinforcement of the concepts; she went on to emphasize the importance of the audience questions while her group was presenting. The audience questions “stretched my mind,” she told the researcher in her interview.

Finally, there were two students who gave answers that seemed to conflict with earlier data. Selma and Winter were both classified as Emergent during the first two phases of the lab, though Selma thought she was at Deep understanding, by claiming in her learning log on day one that she "pretty much already knew what was happening". The following day, however, after the Preparation of her White Board, she wrote "I figured out how the distance and velocity graphs matched up with each other when we drew the graphs. I also learned realized [sic] that on the velocity-time graph, when the line goes across 0, it either means the golf ball hit the table or reached the crest". After the first full day of Presentations, Selma wrote "I realized that negative only means direction." During the interview process, Selma admitted that until the Presentations, she "didn't realize how much I didn't know". This was similar to Winter, who stated that the earlier stages were "simple" so there were not many aha moments. It may be worthwhile to note that, while not formally measured, Winter certainly appeared to have the most "aha" moments, perhaps due to the excitement she expressed whenever she made a breakthrough. The apparent conflict is between these two Emergent girls' sentiments that the early stages were not all that useful to them, while two Deep students earlier expressed the value of the Analysis phase.

Written vs. Presentation

A second question posed to interviewees was whether they thought they would learn more if this lab were run in a way more commonly done in their Physics class, with students providing written responses to questions on a lab sheet, which are then turned in for a grade. The responses were clear and convincing: fully twenty-one students

responded that they learned more in this lab through the White Boarding method. The explanations were heavily focused on the value of group discussion and working with others to solve problems. Quinley, for example, pointed out that collaboration “sparks” the thought process, while Michelle expressed that a written lab would be more difficult, as she would have “no chance to ask questions of others, and learn from them.”

The solitary student who responded that he would not mind a written lab, stated non-committedly that “written would be fine” as he simply preferred the written aspect “a bit more”. He went on to state, “having to think it through is what helps”. In other portions of the interview, however, he stated that “class collaboration” was very helpful to him, and further questioning suggested that the Presentation phase was very helpful to him, as well.

Student Presentations vs. Teacher Led Discussion

A much more controversial topic was addressed in the follow-up to the previous question. Students were asked if they felt they would have learned as much if, instead of student-led presentations, the teacher had led a class discussion about the same situations encountered in the lab. Students responded with split reactions—twelve students claimed that student-led presentations were the way to go and eight students argued that a teacher-led discussion would be better for them. Many of the students expressed that either method would be good, but when pressed, stated that one was slightly more valuable than the other. When looking only at students who were firm in their response to this question, the split was eight to five, favoring student-led

presentations. Two students could not make up their mind between the two options, and were thus labeled as non-responsive to the question.

The surprising aspect about the answers to this question was that the same arguments were used to support both opinions. The debate mainly centered on whether the student-led discussions, which sometimes went in the wrong direction, were helpful. As an example, consider Doug and Dana, who were interviewed together. Doug supported a teacher-led discussion, because students sometimes have misconceptions that confuse the class. Dana countered that a student-led discussion was better at exposing those misconceptions. George felt that other people's struggles and going off track helped, as issues were later resolved. Counter that with Isabel's feeling that students' wrong explanations were a hindrance, so a teacher-led discussion "might be better". Vanessa argued both sides in her interview, stating that while she learned more about her *own* project by having to present, she would have preferred teacher-led discussion for the other groups because "students can be misleading at times."

Another common theme of the pro-student base was the aforementioned "pressure" of having to present to others. Several students combined this with the "confusion is helpful" argument. Emergent student Uma was most vocal about this, stating quite literally that "Total confusion is helpful" and that the pressure of having to present was also helpful. As she eloquently put it, in the student-led discussion there is "no slacking off, you are part of the process."

Both Amy and Lenny pointed out that students "ask different questions" of each other than they do of the teacher. While Amy felt this argument was enough to swing her vote to the student-led side, Lenny felt he could still go either way on this question. He was listed as non-responsive. One other argument for student-led discussions was that a teacher-led discussion would lead to students "zoning out", according to Rose.

From the pro-teacher led contingency, the common feeling was that, as Michelle succinctly stated, "Other students don't explain it right." Likewise, Xena felt that teacher-led was better, as students' wrong statements "stick in my head". Steve felt that teacher-led was better "since points can be led out and organized better."

Additional Student Thoughts about White Boarding

The final question posed to students in the interview was whether they had any additional comments or thoughts they would like to share about the White Boarding experience. While ten students had nothing more to add, twelve of the students used the opportunity to indicate that they enjoyed the White Boarding process. Lenny went so far as to state that, in his opinion, the White Boarding process is "positive, constructive, and [promotes] mental building skills."

Not all students enjoyed the experience, however. Michelle, the student who came out of the Analysis phase designated as Confused and ultimately finished as Emergent, stated that she was "not a fan" of the White Boarding process. She went on to point out that she did not attend this school district until her junior year. Therefore, this was her first experience with White Boarding, whereas the rest of the students already had an idea of what to expect from previous science classes.

Another student, Steve, stated that while he likes the White Boarding process, the similar presentations and repetitive nature “gets old”. He reflected the same sentiment at the end of his learning log when he stated, “…so it was basically review after review after review. Not that it wasn’t helpful, it was just a bit drawn out.”

The most disconcerting statement came from Nick, a student who entered the lab with a Deep understanding. In the interview he stated that off-track students are “frustrating”. In his learning log, he took the time to be more specific: “I feel like I could understand if I did it myself. Some people are on the wrong track, they ask questions, and get everyone else confused. I would rather not be made to ask questions for a grade. I don’t want to ask a question I already know the answer to just to get a good grade.” While Nick’s feelings are understandable and regrettable, he also seems to be missing the concept that even if *he* already knows the answer, his question is helping the students presenting, as well as other audience members, to improve *their* understanding, by making them critically think about ideas.

Chapter 5 – Conclusions

The purpose of this study was to investigate how White Boarding helps students learn. The primary question the study sought to answer was: What specific aspects of the White Boarding process support student understanding? The data suggests that the first of two hypotheses going into the study—that all three aspects of the White Boarding would support student learning—was correct. In each phase of the lab, there were students who were documented as having “aha” moments. Moreover, the student interview data found each phase represented when participants were asked what the most important aspect of the lab was for them. There was also evidence that both the Preparation and Presentation phases led to an improvement in student understanding, as indicated by an increase in the understanding level at which they were coded. Unfortunately, there were no data to measure the increase in understanding for the data Analysis phase, as student understanding of graphing was not evaluated before the lab began.

The second hypothesis was that each of the three phases of White Boarding would be equally represented in terms of the number of students whose understanding was best supported. On the surface, this appears to be an incorrect hypothesis; the Presentation phase resulted in more student votes for the most important aspect of the lab than Analysis and Preparation phases combined, and was also associated with nearly twice the number of “aha” moments than the other two phases combined. Furthermore, eleven of the twenty-eight students in the study demonstrated an

increase in their level of understanding during the Presentation phase of the lab. Keep in mind, however, that there were six students who were already classified at the deep level of understanding prior to this phase, and yet another six who were labeled as Unclassified at the Preparation stage and thus, by definition, could not have demonstrated a level of improvement. Therefore, a more accurate statement is that eleven out of a possible sixteen students demonstrated an increased level of understanding during the Presentation phase. This alone is an impressive number.

The only argument that could be made against the superiority of the Presentation phase is that it lasted two to three times longer than either of the other two phases. If one did want to give weight to the time issue, it could be argued that the phases were quite similar to each other in terms of “aha” moments per class hour. The Presentation phase had eighteen “aha” moments spread over a total of two and a half days, for a rate of about seven moments per class day, very similar to the five “aha” moments per class day found in the Analysis phases and the six per day in the Preparation phase. However, the working hypothesis spoke only of the learning that would take place in each phase, without a consideration of the unbalanced amount of time spent in each phase.

Several other unforeseen conclusions also became apparent over the course of this study. One of these was the nearly unanimous consensus of interviewed students that they preferred White Boarding and the associated Presentations to the more traditional written responses to questions on a lab sheet. This goes hand in hand with

the very common, though not unanimous, sentiment that White Boarding is an enjoyable process from the students' point of view.

Another unforeseen conclusion dealt with how the teacher managed the class discussions. While not formally addressed at any point in the study, the teacher/researcher in this study was concerned about the proper amount of "stepping in" during the presentations. If done too much, the experience would lose the student-driven aspect. This could have led to students who did not experience the pressure of the Presentation. On the other hand, a teacher who stepped in too little would risk the confusion becoming overbearing for some students. This could result in those students completely shutting down in some cases. During the student interviews, the involvement of the teacher was brought up from time to time. It was reassuring to this researcher that the students felt that the teacher involvement was just about right. For example, Craig specifically stated during his interview that the teacher stepped in the proper amount, not controlling the conversation, but also keeping the discussion on track.

Implications

The results of this study seem to confirm that even just an occasional White Boarding experience is beneficial to student learning. While a classroom that is fully invested in the Modeling method is intriguing, there can be some satisfaction in knowing that White Boarding can be reserved for effectively addressing the most difficult concepts in a science curriculum.

It is also possible that the occasional White Boarding experience is beneficial from the attentiveness perspective. The three phases of the experience provide a little something for everyone, and the entire process is a deviation from the standard classroom procedures. The variety that a White Board lab provides may help increase the student attention in class. An increase in student attention would seem conducive to better student learning.

One must also consider that the reported enjoyment of the White Boarding process may be related to the infrequency of its use. If White Boarding were used full-time, would the students enjoy the process as much? If the answer to this question is "no", then it would seem that moderation is key. The argument here is that if students enjoy it, they will put more effort into the process, and get more out of it, as well. If a full-time White Boarding classroom led to a decrease of student interest, the students would likely not learn as much from any given lab. If this argument is accepted, it actually supports the occasional White Boarding experience over the fully committed Modeling classroom.

A further implication of this work might be a warning to anyone interested in employing White Boarding – the data suggest that all three phases of the process must be used. The Analysis, Preparation, and Presentation stages each supported learning for different students. While it may be tempting to cut out one phase of the lab in some situations, the results of this study suggest that such cuts would come at the loss of a learning opportunity for some students.

Limitations

While the findings of this study seem to be definitive, they apply to this particular classroom, with this particular demographic of students, and this particular teacher. They may or may not generalize to other science classrooms. Also, there are other factors that may have confounded the results. In particular, the students in this class were also expected to complete Minds on Physics internet modules (MOP's), available through The Physics Classroom (physicsclassroom.com). While some class time was provided to complete the modules, most students had to spend at least some time doing these as homework. Both Michelle and Yana stated in their learning logs that relating what they were doing in the lab experience to what they were learning while doing MOP's was helpful. This suggests that for these students, at least, the combination of different learning methods was useful.

There were several difficulties encountered over the course of this study. It was initially planned that every two groups of students would have one videographer with them during the Analysis and Preparation phases, in addition to the video of the Presentations. In the end, however, there was but one tripod mounted video camera for the entire class during both the Analysis and Preparation phases. Students were encouraged to walk up to the camera to document their progress and any "aha" moments that they had, but in the end they were too occupied with their Analysis and Preparation to reflect on what they were learning to the camera. The resulting footage from those two days was a jumble of voices and sounds that, for the purposes of this study, was found to be useless.

Additionally, it was frustrating to the researcher to not be able to quantify an increase in level of understanding during the Analysis phase. If this research were to be repeated, there would be value to classifying the level of understanding of key concepts that each student had prior to beginning the lab.

Future Research

The Modeling method places at its core "an emphasis on the construction and application of conceptual models of physical phenomena as a central aspect of learning and doing science" (Jackson, Dukerich, & Hestenes, 2008, p.10). While I see great value in this emphasis, I also see value in what I am currently doing with my physics classes. My teaching currently places an emphasis on preparing students for college physics and engineering courses, with special attention paid to Free Body Diagrams (FBD's). A co-emphasis of the class is to help students see the relevance of physics to everyday life, and to eliminate, or at least address, common student misconceptions. A Modeling teacher would argue that their class prepares students not only for college physics and engineering courses, but to be life-long learners and observers of the natural world as well (Jackson, Dukerich, & Hestenes, 2008).

The argument of the Modeling advocates is making an impact on me. While completing the literature review for this paper, I found myself ever more intrigued with the Modeling method of teaching. The possibility of switching to White Boarding full-time has been considered seriously numerous times. The creators of the FCI have been gracious enough to share that tool with me, and I now look forward to testing my own students at the end of the year. While my interest in Modeling has indeed risen, I am

also comfortable with the level of college readiness my students achieve. Informal interviews with graduates who invariably come back to visit verify that my physics course at Houghton High School (HHS) has prepared them well for first semester physics at a variety of different public and private universities. While that in itself gives me confidence about the current methods, who is to say that employing the Modeling method full-time would not result in even more prepared students? This is where the FCI testing will be very informative, and provide some direction for the future of HHS physics. If my students achieve results on the FCI that are similar to what Modeling teachers achieve, I can be confident in the current state of the class, and instead focus future course improvements on tweaking the existing system. If my students are considered pre-Newtonian, or in other words score on average below 60% on the FCI, a more radical change may be justified. Interestingly, I have confidence that my students will do quite well on the FCI.

Another resource used in my classroom is the aforementioned Minds on Physics internet modules. Developed by teachers from Glenbrook (IL) South High School, and hosted at physicsclassroom.com, these modules attack the most common misconceptions students bring to the classroom. The use of Minds on Physics, combined with classroom reinforcement, and occasional White Boarding exercises, may be found to be a successful combination, perhaps even as successful as full-time Modeling. I am excited to see the results.

Yet another potential study would involve comparing a teacher who utilizes the Modeling method full time in their classroom, with a traditional teacher who does no

White Boarding labs, but utilizes the Minds on Physics extensively. As my classroom uses a combination of these techniques, I think it would be interesting to examine the potential synergistic effect of combining the two methods.

Summary

Although stated previously, it is important to note once again that the findings of this study apply to this particular classroom, with this particular teacher. The researcher in no way intends to suggest that occasional White Boarding is superior to a full-time Modeling classroom. The implication of the study is that for a teacher who is interested in Modeling, but not willing to commit fully, a part-time usage can be effective in supporting student learning. Those who have committed to Modeling full-time have reported great satisfaction and astounding results. Now one person, at least, has reported similar results for the occasional usage of White Boarding.

References

Arons, A. B. (1990). *A guide to introductory physics teaching*. New York: John Wiley.

Ball, W. H., & Brewer, P. (2000). *Socratic seminars in the block*. New York: Eye on Education.

Barclay, W. L. (1985). *Graphing misconceptions and possible remedies using microcomputer-based labs.* (Report No. TERC-TR-85-5). Cambridge, MA: Technical Education Research Center. Retrieved from ERIC database. (ED264129)

Blanton, P. (2008). Using interactive whiteboard to enhance student learning. *The Physics Teacher*, *46*(3), 188-189.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics*, *50*(1), 66-71.

Halloun I., & Hestenes, D. (1985a). Common-sense concepts about motion. *American Journal of Physics*, *53*(11), 1056-1065.

Halloun I. A., & Hestenes, D. (1985b). The initial knowledge state of college physics students. *American Journal of Physics*, *53*(11), 1043-1055.

Henderson, C., & Dancy, M. H. (2009). Impact of physics education research on the teaching of introductory quantitative physics in the United States. *Physics Review Special Topics: Physics Education Research*, *5*(2), 1-9.

Hestenes, D. (1987). Toward a modeling theory of physics instruction. *American Journal of Physics*, *55*(5), 440-454.

Hestenes, D. (2006). Notes for a modeling theory of science cognition and instruction. In van den Berg, E., Ellermeijer, T., & Slooten, O. (Eds.). *Proceedings of the 2006 GIREP conference: Modelling in Physics and Physics Education*, Amsterdam, Netherlands: University of Amsterdam. Available at http://www.science.uva.nl/research/amstel/dws/girep2006/index.php?PageName=articles

Hestenes D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141-158.

Jackson, J., Dukerich, L., & Hestenes, D. (2008). Modeling instruction: An effective model for science education. *Science Educator*, *17*(1), 10-17.

Lattery (2007). *Introduction to the modeling method: Cards, Ptolemy, and a new way of teaching physics.* Available at http://www.phys.uwosh.edu/lattery/_docs/art_mm_intro.pdf

Linn, M.C., Layman. J., & Nachmias, R. (1987). Cognitive consequences of microcomputer-based laboratories: Graphing skills development. *Contemporary Educational Psychology*, *12*(3), 244-253.

McDermott, L. C., Rosenquist, M. L., & van Zee, E. H. (1987). Student difficulties in connecting graphs and physics: Examples from kinematics. *American Journal of Physics*, *55*(6), 503-513.

Michigan Department of Education (2006). *High school content expections/Science/Physics*. Available at http://www.michigan.gov/documents/Physics_HSCE__168208_7.pdf.

Nemirovsky, R., Tierney, C, & Wright, T. (1997). *Body motion and graphing*. (Report No. TERC-WP-2-97). Cambridge, MA: Technical Education Research Center. Retrieved from ERIC database. (ED466394)

Svec, M. T. (1995). *Effect of micro-computer based laboratory on graphing interpretation skills and understanding of motion.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (San Francisco, CA, April 23, 1995). Retrieved from ERIC database. (ED383551)

Tanner, B. M., Bottoms, G., Feagin, C., & Bearman, A. (2003). *Instructional strategies: How teachers teach matters.* Atlanta, GA: Southern Regional Education Board.

Vernier (2011). Logger Pro [Computer software]. Beaverton, OR: Vernier Software and Technology.

Wells, M., Hestenes, D., & Swackhamer, G. (1995) A modeling method for high school physics instruction. *American Journal of Physics*, *63*(7), 606-619.

Appendix—IRB Documents

MichiganTech
Michigan Technological University

Office of Research Integrity
and Compliance

302 Lakeshore Center
1400 Townsend Drive
Houghton, MI 49931
906.487.2902

MEMO

TO: Dr. Shari Stockero, CLS

CC: Tony Schwaller, CLS

FROM: Joanne Polzien, Director Research Integrity and Compliance [redacted]

DATE: August 26, 2010

SUBJECT: Approval M0640

Your application to use human subjects in research or classroom situations has been reviewed with the following determination:

Protocol #: M0640
Protocol Title: "The Effects of White Board Presentations on Student Learning"
Approved Dates: August 26, 2010 through August 25, 2011

Approvals are granted for up to a one year period. You will need to request a continuation for each year of the project six weeks prior to the end date indicated above for each year of the project. The Office of Research Integrity and Compliance will make every effort to send the Principal Investigator annual reminders. However, the Principal Investigator is responsible for submitting annual Continuation Forms in advance of the expiration date for the project. It is very important that these expiration dates are not missed. Failure to submit annual review materials on time will result in the termination of this protocol.

This approval applies only for this project, and only under the conditions and procedures described in the application; if any changes are made in the protocol or conditions set forth in the application, the principal investigator must obtain a separate approval before these changes take place. The approved project will be subject to surveillance procedures requiring periodic review. This review will consist of consulting with the principal investigator and examining the appropriate project records.

Individual identification of human subjects in any publication is an invasion of privacy. Before beginning a project involving human subjects, and only if required, the principal investigator must obtain a properly executed informed consent from each subject and/or the person legally responsible for the subject. **If a consent form has been reviewed and approved it has been attached with an official date stamp on it. Only copies of the official date stamped informed consent is to be distributed to participants relating to this project. If any changes or modifications are needed regarding this form, you must first submit the revised document for review and approval prior to use.** The principal investigator must retain informed consent forms on file for at least three years after the end of the project. If a project involves a high level of risk, copies of the signed informed consent forms must be filed with the Human Subjects Committee; if this is the case, you will be notified.

This document is on file in the Office of Research Integrity and Compliance. If you have any questions, please contact me at 487-2902 or jpolzien@mtu.edu.

Dear Student and Parents/Guardian,

I am working on a research project through Michigan Technological University as part of my Masters of Science in Applied Science Education. My research project is aimed at understanding how students learn during the preparation and presentation of White Board labs in Physics. I request permission for your child to participate in this project.

The study will consist of:

1. Participating in White Board Presentations that focus on discussing and analyzing a lab experiment.
2. Giving me permission to use student work as part of the data for my study.
3. Allowing me to videotape some portions of student work and/or class discussions.
4. Possibly participating in an interview.

Only my advisor, Dr. Shari Stockero, and I will have access to information from your child. At the conclusion of the study, your child's individual results will be reported as a group result only; individual student work will not be identified by name. If a particular student is quoted or mentioned, they will be given an anonymous label, such as "Student A".

Participation in this study is voluntary. The decision whether or not to participate in the study is determined by the student and the parent/guardian. Your decision whether or not to participate in the project will not affect the normal services provided to your child from Houghton-Portage Township Schools, nor will it be factored into the Physics grade. The student will still be responsible for the material taught during the unit. If the student agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights or remedies because of your participation in this research study.

Should you have any questions or desire for further information, please contact me by calling the school (906)482-0450 or emailing me at tschwaller@houghton.k12.mi.us or contact Dr. Shari Stockero at (906)487-1126 or stockero@mtu.edu . Please keep this letter. Complete and sign the second page, and have your child return it to me.

If you have any questions about your student's right as a research subject, you may contact the Michigan Technological University Institutional Review Board (IRB) by mail at 1400 Townsend Drive, Houghton, MI 49331, by phone at (908) 487-2902 or by email at jpolzien@mtu.edu.

Sincerely,

Tony Schwaller	Dr. Shari Stockero
Houghton High School teacher	Assistant Professor
	Michigan Technological University

Parental Consent

The Effects of White Board Presentations on Student Learning

Please indicate whether or not you wish to allow your child to participate in this project by checking the statements below, signing your name and having your child return this page to me. Keep the letter for your record.

______I grant permission for my child to participate in Tony Schwaller's study of The Effects of White Board Presentations on Student Learning.

______ I **do not** grant permission for my child to participate in Tony Schwaller's study of The Effects of White Board Presentations on Student Learning.

______________________________ ______________________________

Signature of Parent/Guardian Printed Parent/Guardian Name

______________________________ __________________

Printed Name of Child Date

Student Assent to Participate in Research

I have read and understand the terms defined in the letter to students and parent/guardians for Tony Schwaller's research project on The Effects of White Board Presentations on Student Learning. If I have questions, I understand that I can ask them at any time during the classroom unit or I can contact Mr. Schwaller by emailing him at tschwaller@houghton.k12.mi.us.

Please check one of the following, and return this page to Mr. Schwaller. Again keep the letter for your records.

______I do agree to participate in Mr. Schwaller's study of The Effects of White Board Presentations on Student Learning. I have read the letter and understand its terms and I agree to these terms.

______ I do not agree to participate in Mr. Schwaller's study of The Effects of White Board Presentations on Student Learning. I do not wish my class work or scores to be used in the study.

______________________________ ______________________________

Signature of Student Printed Name of Student