THE EFFECTS OF INQUIRY INSTRUCTION ON PROBLEM SOLVING AND CONCEPTUAL KNOWLEDGE IN NINTH GRADE PHYSICS CLASS

by

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STATEMENT OF PERMISSION TO USE

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ABSTRACT

This project documents the impact of inquiry instruction on two ninth grade physics classes. Problem solving skills, conceptual knowledge, and students' reactions to the teaching style were assessed while students studied rotational motion and energy. Students showed improvements in both problem solving skill and conceptual knowledge when they learned a topic using the inquiry model. Students generally preferred the traditional, non-inquiry style lessons.

INTRODUCTION AND BACKGROUND

Project Background

This paper documents a project based on the action research model to study the effects of inquiry-based learning on the problem-solving skills and the conceptual physics knowledge of my students. I teach two sections of ninth grade physics at Tower Hill School, an independent college preparatory day school in Wilmington, Delaware. Tower Hill has 756 students in pre-kindergarten through the twelfth grade. It is one of the top day school in the region, so Tower Hill can select high achieving students for admission. At present twenty percent of the student body is ethnic minorities. The administration is aggressively improving financial aid opportunities in order to have a broader economic background within the student body. The percentage of students receiving financial aid is still quite low at 19% ("About Tower hill," n.d).

I have taught ninth graders for nine years at Tower Hill. During that time I changed the course from physical science into a physics first course that emphasizes problem solving. For the last two years I have only taught two of the four ninth grade sections. This year one class has fifteen students while the other class has sixteen students. Science courses are not tracked at Tower Hill. Math courses, on the other hand, classes have three tracks. This can lead to unofficial tracking in sciences classes. It is hard to evenly distribute the three math tracks into science classes. This year my first period class has five advanced math students and four lower level math students while my second period class has ten advanced math students and zero lower level math students.

The ninth grade curriculum centers around Newtonian mechanics, the study of motion and forces. A primary goal of the course is to develop student's problem solving skills for use in upper level science courses.

This interest in developing problem solving skills led me to my primary focus question: Will inquiry-based instruction improve student's problem-solving ability? As a sub-question, I want to know if inquiry-based instruction can improve student's conceptual knowledge of Newtonian mechanics. I am also interested in whether students like learning from an inquiry model.

CONCEPTUAL FRAMEWORK

Problem solving is the process of working towards a goal where the path to the goal is uncertain (Martinez, 1998). When describing the importance of teaching problem solving, Martinez calls it "the process of working towards a goal without a script" and this is "the cognitive passport to the future" in this constantly changing world (p. 606).

Polya's (1957) book on problem solving serves as background for more recent research on the process of problem solving. Polya's problem solving process can be summarized by the following steps: understand the problem, make a plan, follow the plan assessing each step as you work, and assess the solution. Understanding the problem, Polya's first step, is critical to solving it. Chi and VanLehn (2010) found that when students are trained to identify and understand the concepts behind the problems, the gap between good problem solvers and weak problem solvers diminishes.

Qualitatively describing the problem helps students understand the problem. Dhillon (1998) described qualitative analysis as an essential activity in problem solving.

Students taught to describe problems with a diagram and to assess the diagram for consistency had an advantage in problem solving (Heller & Reif, 1982). Multiple representations of problems are helpful for problem solvers (Rosengrant, Etkina, & Van Heuvelen, 2007).

Once the problem is understood, it is essential that students assess their work. They should make sure that each step makes sense and that the answer makes sense. Providing explicit instruction on how to diagnose errors in problems improves student's assessment abilities. For example, if students are taught to express all answers on their diagram, they will more easily catch mistakes like sign errors or not solving for the right quantity. (Yerushalmi, Mason, Cohen & Chandralekha, 2008).

Traditionally taught physics classes do not effectively teach problem solving. In these classes, students learn physics concepts through lectures. The teachers show students how to do problems. The students later practice similar problems on their own. This type of passive learning, where the teacher gives the information to the students, is not effective for learning physics concepts nor for gaining skill at problem solving (Hewitt, 1987; McDermott, 1991; McMillan & Swadener, 1991; McDermott, 1993; Kahle & Damnjanovic, 1994; Redish, 1994; Thacker, Kim, Trefz, & Lea, 1994; Falconer, Mangala, Wyckoff, & Sawada, 2001; Ates, 2005). In traditionally taught classes, students find the most efficient route to success is algorithm memorization and plug and chug rather than trying to understand the concepts or the problems (Hammer, 1989). McDermott (2001) found that students taught by traditional methods made negligible improvements in their misconceptions about physics concepts from the beginning to the end of an introductory physics course. In another study, she found no improvements on final exam performance in introductory physics students between students who attended traditional lectures and those that did not attend any lectures (1991).

Active learning, where students develop the concepts for themselves, improves students' learning of physics concepts (Hake, 2000). Dewey (1916) introduced the idea of active learning. Constructivism states that knowledge is not a separate entity from the learner, but is constructed by the learner as they learn. Inquiry is a form of active learning with roots in constructivism. The National Science Standards (National Research Council, 1996) considers learning through inquiry to be an essential part of science education. Inquiry, according to the Standards, involves formulating questions, designing investigations, making observations, developing explanations and communicating the explanations. When students learn through inquiry, they develop their understanding of the material rather than being told about the material. They are actively learning the content while at the same time they are learning to do the process of science (National Research Council, 2000).

An inquiry-based classroom treats the students as a community of investigators. The focus of the learning is on the students. They learn to formulate theory from observations. They learn to communicate what they have learned. They question each other, ensuring that what is learned is backed up by observations (Llewellyn, 2005).

A class of early childhood education majors taking an inquiry style physics course outperformed engineering majors taking a traditional physics course on qualitative and quantitative problems on their exam (Thacker et al., 1994). Inquiry learning can take time away from practicing problems, however, students using inquiry still develop greater skill at problem solving than traditionally taught students (Shaffer & McDermott, 1992).

Laws (1997) has run into some difficulty in trying to implement Workshop Physics, an inquiry curriculum, into her introductory physics course. Students who are used to the traditionally taught class can find inquiry learning frustrating. They are used to copying the concepts down from the board, not coming up with the concepts from their observations. They can take the position that the teacher is supposed to be doing the teaching, not the student. The teacher is certainly still teaching in inquiry learning, however, they are not the focus of the learning process; the student is the focus. Overcoming these frustrations is crucial since student attitude about science has been found to be more important than intelligence, economics, and number of high school science courses taken for success in class for college science students (Hestenes, Wells, & Swackhammer, 1992; Adams, 2008).

Educators have developed instruments for assessing progress in conceptual understanding and problem solving in physics classes. The Force and Motion Concept Evaluation (FMCE) is a multiple-choice test designed as a pre- and post-test of force and kinematics conceptual understanding (Thronton & Sokoloff, 1998). The Mechanics Baseline Test (MBT) is a multiple-choice test designed as a post-test for assessing student’s success at connecting mechanics concepts with problem solving (Hestings & Wells, 1992).

METHODOLOGY

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. Students took home a Consent Form to be signed by their parents before the treatment began (Appendix A). My division head signed an Administrator Approval Form giving permission to proceed with the project (Appendix B).

The three-month treatment involved implementing an inquiry-based curriculum for the rotational motion portion of the Newton’s Laws Unit and the Work and Energy Unit (Appendices C & D). For the first two topics, centripetal force and angular velocity, I started off using a traditional style of teaching in first period class and an inquiry style of teaching for the same topics in second period class. For the next two topics, torque and angular inertia, I switched and used inquiry in first period and a traditional style in second period. I switched again before the final two topics: work and conservation of energy. I felt it was important to switch the teaching style between classes to control for different abilities in each class. I know this was done at the cost of having more time to establish an inquiry-learning environment.

After we completed and discussed the introductory lab for each topic, both classes took the Attitude and Comprehension Survey, which probed how well students understood the topic as well as what they liked and did not like about the learning process (Appendix E). I quantified their responses and compared the modes between traditional and inquiry styles.

I also assessed student performance on aspects of the Quizzes (Appendix F) they took on each topic. The traditional and the inquiry classes both took the same quizzes. I compared how the two classes did on conceptual questions. I assessed problem-solving ability by comparing scores between classes from one challenging problem per quiz. I also assessed whether students used a diagram when they worked and whether they put a unit on their answers. The diagram shows evidence of qualitative description and a unit is necessary in order to assess an answer. I compared the two class's use of these problem-solving skills. For each quiz, I quantified the student performance on each category. I compared the means for each category between the inquiry and the traditional class. I ran a t-test on each category to test for statistical significance.

Students wrote Lab Reports (Appendix G) to document most of their lab work. I used the grades students earned on the reports as a measure of their understanding of the material. The quality of the reports also reflected student engagement in the process, which gave me insight into whether they enjoyed working on the labs. I inferred that higher lab grades corresponded to more enjoyment of the process. I compared the inquiry and traditional classes by graphing their mean scores for each lab and running a t-test for statistical significance.

I also gave Informal Ethnographic Interviews to four students in each class two times during the treatment (Appendix H). The interviews assessed conceptual knowledge, problem-solving ability, and their general reactions to the teaching style. I chose two boys and two girls from each class with the full spectrum of ability levels represented. The same students participated in all interviews. I felt it was inappropriate to try to quantify the interview data since I only interviewed eight students. Instead, I took careful notes and used the notes as qualitative data. The order of topics covered as well as assessments given is shown below (Table 1).

Table 1
Treatment Schedule

Topic	First Period	Second Period	Quiz	Lab Report	Survey	Interview
Centripetal Force	Traditional	Inquiry	X	X	X	
Angular Velocity	Traditional	Inquiry			X	
Torque	Inquiry	Traditional	X	X	X	
Angular Inertia	Inquiry	Traditional	X	X	X	X
Work	Traditional	Inquiry	X	X	X	
Conservation of Energy	Traditional	Inquiry	X	X	X	X

I grappled with the ethical issue of using traditional instruction on one class to control for the inquiry treatment. I feel strongly that inquiry is a powerful tool for actively engaging students and I would not want the control group to miss an opportunity for active learning. Upon reflection on my teaching style I concluded that my traditional style also actively engages students. I discussed this issue with my critical friend and teaching partner who routinely sits in on my classes. He said my “Columbo” style of teaching effectively engages the students (T. Hoch, personal communication, November 18, 2010). I often feign confusion or state that I have forgotten a concept and ask my class for help. If it is a tough concept, I don’t get it until multiple students have explained it to me in different ways and then I am able to reiterate the concept using their explanations. Since inquiry and my traditional style both actively engage students, I am comfortable with this methodology of using one class as a control.

For the traditionally taught topics, I introduced the equations by deriving them on the board, then I demonstrated how to use the equations with an example problem, then I gave the class a similar example problem to try on their own. That night I would assign practice problems for homework. The next day we would go over the homework then do a lab that reinforced the theory. The labs typically took between one and three class periods to complete. Each night students were assigned homework problem sets. We went over the problems daily before resuming the lab work. Students typically had four to five homework assignments before they were assessed with a quiz.

Each inquiry style topic began with some sort of demonstration. Students wrote reactions to the demonstration to in their notebooks. For centripetal force, the first topic, I stood at the front of the class spinning an object on a string in a circle with a radius parallel to the floor. After students wrote their reactions in their notebooks, they discussed them with the person sitting next to them and then we had a class discussion about the spinning object. I directed the conversation to the question of what is causing the object to turn in a circle. We came up with the tension in the string and then refined it to say the horizontal component of the force the string is exerting on the object caused the object to turn. The direction of this force was always towards the center of the circle. Next I guided the conversation to what determines the magnitude of this force? We brainstormed a list of potential variables. We discussed the list and narrowed it down to velocity, mass, and radius. I assigned partners the task of designing an experiment to test the effects of one of the three variables on the center seeking force. The process of experimenting took three days. This was typical for an inquiry investigation. During those three days, I did not assign homework. The full class periods were spent experimenting.

Once the experiments were finished, students presented their work. Three groups were formed, one for each variable that was tested. I gave the groups fifteen minutes to come up with a presentation for their work. The rest of the class took notes during the presentations and would use their notes to write a lab report. I emphasized to the class the importance of skillfully questioning each other's work. This was their first crack at this type of inquiry and after the first presentation there were no questions. I stepped in and modeled some appropriate questions. The class took over once they got the idea that they needed more information if they were going to write a lab report.

After the presentations, I used their data to come up with an equation for centripetal force. I defined centripetal force and modeled an example of how to use the formula in a problem. That night they had their first homework problem set. They typically only had two problem sets before they were given a quiz on the material.

At the end of the treatment, both classes took portions of the Force Motion Concept Evaluation (FMCE) and the Mechanics Baseline Test (MBT) as post-tests. Students only saw questions form the tests that evaluated the topics that Class A learned with a traditional model and Class B learned with an inquiry model. The FMCE probed improvements in conceptual knowledge. The MBT gave insight into student's ability to apply the conceptual knowledge to problem solving. I scored responses and compared the classes to each other. I ran a t-test to look for statistical significance. A variety of assessments were used to provide a thorough documentation of the treatment (Table 2).

Table 2
Data Triangulation Matrix

Research Question	Data Source 1	Data Source 2	Data Source 3
Can inquiry based instruction improve student's problem solving skills in physics class?	Survey	Informal Ethnographic Interviews	Tests, Quizzes, MBT
Can Inquiry based instruction improve student's conceptual understanding of Newtonian mechanics?	FMCE pretest and posttest, Survey	Informal Ethnographic Interviews	Tests, Quizzes, MBT
Can Inquiry based instruction improve enjoyment of physics class	Informal Ethnographic Interviews	Survey	Lab Reports

DATA AND ANALYSIS

Independent-samples t-tests were used to compare quantitative data between the two classes (N = 15, N = 16). An alpha level of .05 was used for all tests and two-tailed p-values from the tests were reported on the graphs. The effect of teaching style on problem-solving ability between classes was analyzed by comparing the scores on one difficult problem from each quiz. Problem-solving scores on the Centripetal Force Quiz were significantly higher for inquiry instructed students (*M* = 4.31, *SD* = .602) than for traditionally instructed students (*M* = 3.73, *SD* = .458), *t*(29) = 3.01, *p* = .00264, *d* = 1.08. A similar pattern is seen on problem-solving scores from the Work/Energy Quiz where inquiry instructed students (*M* = 5.69, *SD* = 1.01) scored significantly higher than traditionally instructed students (*M* = 4.31, *SD* = 1.03), *t*(27) = 3.63, *p* < .001, *d* = 1.35. The teaching style was reversed between classes when torque was introduced. The performance trend on problem-solving scores from the Torque Quiz also reversed: the traditional class ($M = 3.43$, $SD = 2.38$) earned a higher average score than the inquiry class ($M = 2.50$, $SD = 2.13$). The difference between the two classes was no longer statistically significant, $t(28) = 1.13$, $p = .136$, $d = .412$. The patterns observed on difficult problems from the quizzes are seen again when comparing the total percentages form all of the problems on the quizzes (Figure 2).

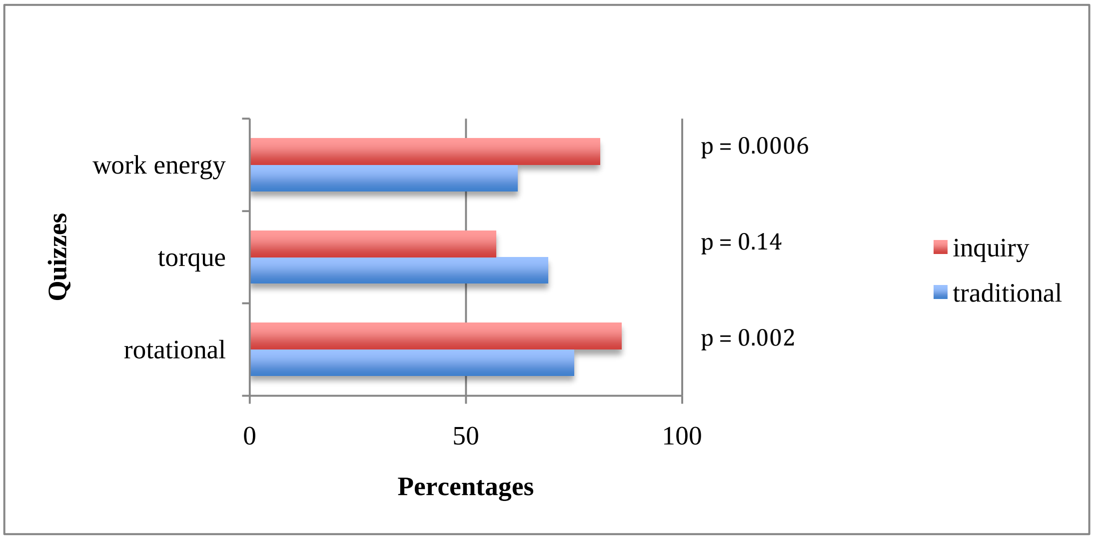

Figure 1. Problem solving scores on Quizzes, (*N*=31).

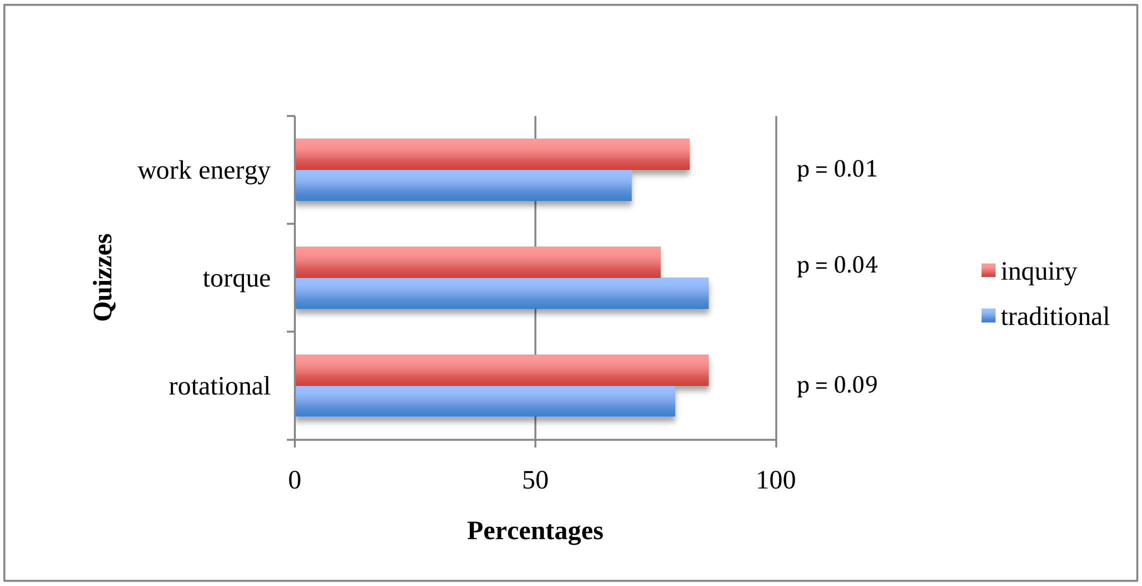

Figure 2. Quiz averages, (*N*=31).

Quizzes were also assessed for conceptual knowledge. The inquiry students outperformed the traditional students for every topic (Figure 3). Students gave insight into learning the concepts through inquiry. Some students mentioned that inquiry helped them to remember the concepts, “I prefer inquiry, I remember it better if I have done it myself,” or “we had to figure things out ourselves and I think this method imprinted it in my brain.” Many student comments referred to the power of inquiry for helping them to understand the concepts, “it helps me to understand it better when we work to get the equations,” or “it helped me to understand why the equations work the way that they do,” and “I think that by coming up with the equation as a class by collecting data, we will have a better understanding of torque.”

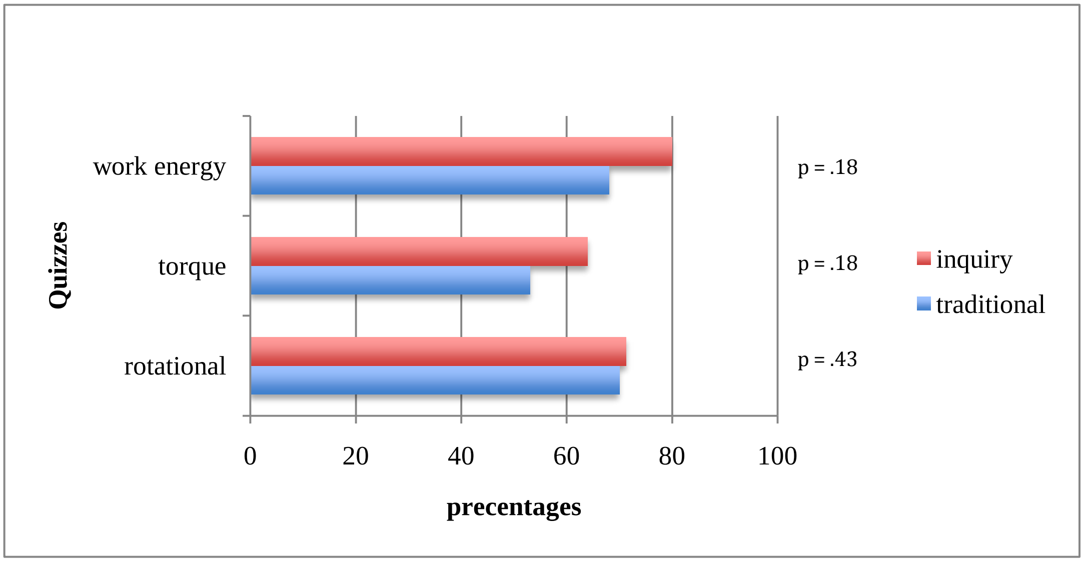

Figure 3. Conceptual scores on Quizzes, (*N*=31).

Average scores on the centripetal force lab report triangulate with student comments and the conceptual scores on the quizzes. The inquiry group (*M* = 88.6, *SD* = 8.47) did significantly better *t*(29) = 3.33, *p* = .00121, *d* = 1.19 than the traditional group (*M* = 77.4, *SD* = 8.47). Scores on other labs fluctuate back and forth between inquiry and traditional doing better. None of the other scores showed statistically significant differences between inquiry or traditional styles of teaching (Figure 4). The FMCE scores showed the traditional group (*M* = 1.73, *SD* = 1.39) had a better conceptual understanding of energy than the inquiry group (*M* = 1.125, *SD* = 1.59). The difference was not statistically significant, *t*(29) = 1.12, *p* = .132, *d* = .405 (Figure 5).

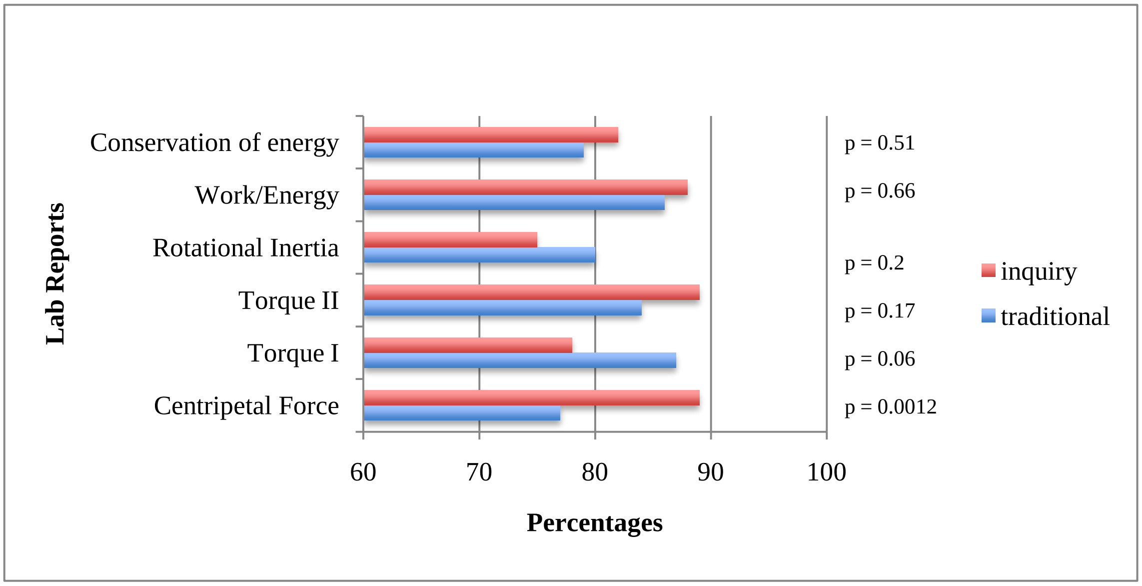

Figure 4. Lab report scores, (*N*=31).

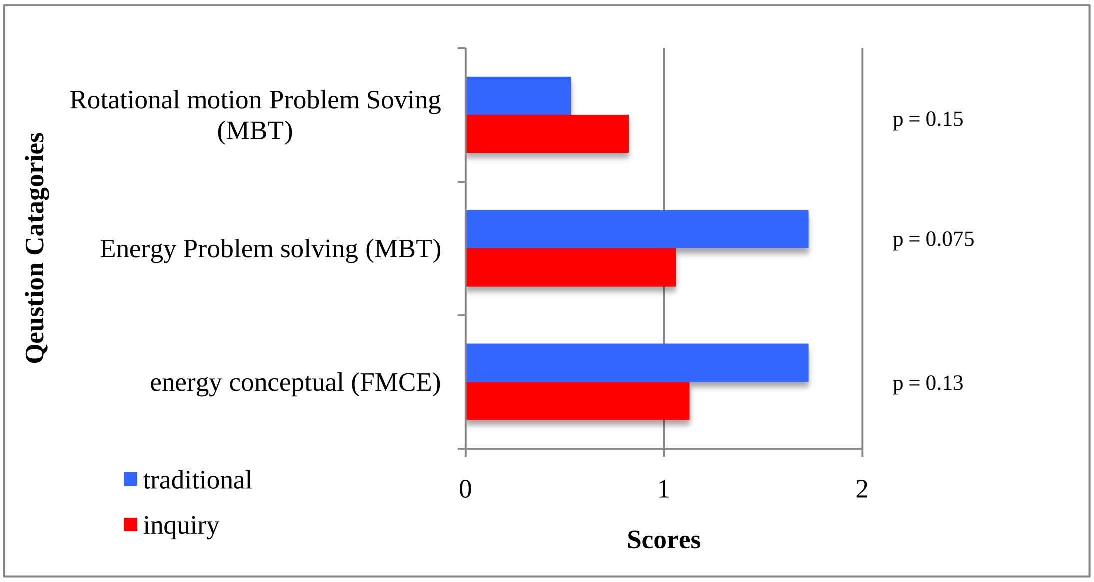

Figure 5. Mean scores on sections of the MBT and FMCE, (*N*=31).

Students indicated that they enjoyed learning a topic more when it was taught traditionally than they did when it was taught through inquiry (Figure 6). Comments included, “traditional is always better because we know what we are doing,” and “It [traditional] was more straight forward,” or “traditional was effective because we had more time for practice problems." I saw numerous of comments like, "traditional please!" One student gave some insight when she said, "traditional is more like what I am used to from other classes."

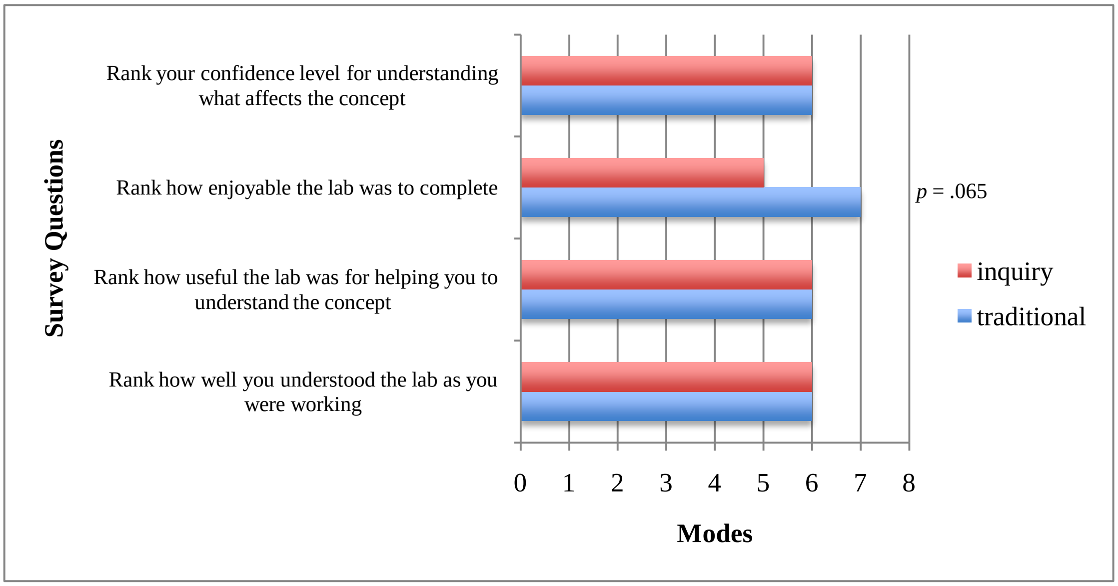

Figure 6. Modes form Attitudes and Comprehension Survey, (*N*=31).

INTERPRETATION AND CONCLUSION

The problem solving scores from the quizzes support the statement that inquiry learning improves student's problem-solving ability. This is especially true when you take into account the different ability levels between the two classes. When the stronger class learned centripetal force through inquiry they earned significantly higher scores on a difficult problem on the quiz (*M* = 4.31, *SD* = .602) than the traditional class (*M* = 3.73, *SD* = .458), *t*(29) = 3.01, *p* = .00264, *d* = 1.08. When the teaching methods were reversed for the torque unit, the stronger class still earned higher problem-solving scores (*M* = 3.43, *SD* = 2.38), than the weaker class (*M* = 2.50, *SD* = 2.13), however, the difference was no longer statistically significant, *t*(28) = 1.13, *p* = .136, *d* = .412.

The Mechanics Baseline Test gave some confounding data. The traditional class, which was the weaker class, outperformed the inquiry class on energy problems. The energy unit was the last unit of the treatment and I had to rush the discussion of the topic for the inquiry class. Instead of having the class interpret each other's the data, I presented and interpreted the data. One student commented that the discussion followed more of a traditional model. I knew the discussion was a critical component of inquiry learning, but I had the impression that the problem solving in the lab was the more central component of inquiry learning. This data suggests otherwise. Investigating the importance of different components of inquiry learning would be an interesting extension of this study.

The inquiry class out performed the traditional class on all conceptual questions on the quizzes. If it is assumed that good conceptual knowledge is necessary to write a quality lab report, then the centripetal force lab report triangulates well with this data showing a statistical difference between the inquiry ($M = 88.6$, $SD = 8.47$) and the traditional class ($M = 77.4$, $SD = 8.47$), $t(29) = 3.33$, $p = .00121$, $d = 1.19$. Two of the other three lab reports present confounding data. The traditional class did better for these labs. It should be noted that the stronger class was the traditional group for these three labs and the difference was not statistically significant. The FMCE data is also confounding. The questions on the test assessed student's conceptual knowledge of energy. Again, this was the topic where the inquiry class did not have a proper discussion.

This project did not adequately address the question of whether students enjoy studying physics through an inquiry model. The surveys and interviews indicate that students prefer traditional learning because it is easier and more efficient. The lab report scores indicate that students are more engaged in the lab when it is an inquiry lab. I have no doubt that they are more engaged, and I suspect that this indicates that they see the value in an inquiry lab more than a traditional lab. My assumption was higher grades means more engaged, which must mean more enjoyable. I am not so sure about the last part now.

I suspect the preference towards traditional labs is they are perceived to be easier, and easier is better. I have this suspicion because three out of fifteen students stated that they preferred traditional to inquiry labs on their first survey before they had even experienced an inquiry lab. It would be an interesting study to assess student's attitude about inquiry over a larger period of time when they would have a chance to experience working within an established inquiry community. The methodology for this study did not allow students to get used to inquiry since the teaching styles switched back and forth.

VALUE

This report joins the crowded ranks of projects showing the positive effects of inquiry learning in the science classroom. The educational community probably did not need further validation of the benefits of inquiry learning. The project was instead valuable because of the reflection and introspection the process required.

Starting off with rotational motion was interesting because I have not taught this topic in over a decade. I was trying out a new topic using two new teaching styles. My typical style is more of a hybrid of the two styles. It was much easier to prepare to introduce the topic through traditional than it was to prepare to introduce the topic through inquiry. On the first day of the treatment I found it more difficult to introduce rotational motion using the traditional style. I was not used to introducing a topic with a lecture and my students were not used to it either. The students were not engaged and it was obvious that over half of the class was lost midway through the lecture. They dutifully copied down notes, but there was no thinking happening. I pulled them in the next day by pretending to forget what we covered the day before and asking for their help. Once we got moving, the traditional class went smoothly.

I was more nervous about implementing the inquiry method. The initial discussion was superior to the traditional lecture. Students were engaged. We had some trouble with the lab mainly due to technical difficulties associated with doing a new lab with new equipment. Once we overcame the issues, the lab went well. Students knew what they were doing and why they were doing it.

I had to put a lot more thought into running the inquiry class. The extra effort paid off with a more engaged class. I had the technical difficulties worked out by the time the traditional class did their lab. I did not enjoy interacting with the traditional class as much as they worked through their lab. Their questions were not as good. They were more interested in getting the job done with as little effort as possible. This was a pattern for all topics, inquiry was harder to prepare for but easier to implement resulting in more engaged students.

I have taught science for over a decade and I have developed a style that I am comfortable with. It has evolved over time as I tried things and either they worked or they didn’t. The process of doing this project has forced me to really analyze what I do and why I do it. It has brought the idea of active learning as opposed to passive learning to the forefront of my thinking as I reflect on my teaching. It turns out that my style of teaching works because it engages students. Now I will intentionally use this as I develop curriculum. Another guiding principle that the data introduced me to is the power of student lead discussions. I am certainly a novice at this, but even my bumbling attempts at setting up these discussions were effective. I am excited to refine my craft by learning to effectively guide students to interact with each other as they engage the material.

This study has refined my skills for analyzing the effectiveness of curriculum. In the past I used instincts to guide me as I decided how to run my class and what was effective once I tried something new. Now I have the theory and the tools to intentionally design and reflect on my course. I certainly have an effective new teaching tool with inquiry, but more importantly, I have the skills to analyze when to use it, how to use it, and whether it was effective after I use it.

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APPENDICES

APPENDIX A

CONSENT FORM

Appendix A
SUBJECT CONSENT FORM
FOR
PARTICIPATIONIN HUMAN RESEARCH AT
MONTANA STATE UNIVERSITY

Project Title: The Effects of Using Guided Notes for At Risk High School Students

The purpose of this research project examines the use of guided notes in science class and its effect on content understanding, test scores, short and long term memory and science attitude. For this project, students will be asked to complete a Student Notebook Survey, Unit Test, On-Line Post Unit Quiz and a Student Interview as well as several Formative Classroom Assessments. All of these data collection instruments fall within the area of common classroom assessment practices.

Identification of all students involved will be kept strictly confidential. All of the students involved in the research will remain unidentified in any way, and their levels of environmental interaction will be assessed and noted. However, ten students will be randomly selected to participate in an interview concerning the guided note and science class. Students will be selected on availability for the interview during the school day. Nowhere in any report or listing will students' last name or any other identifying information be listed.

There are no foreseeable risks or ill effects from participating in this study. All treatment and data collection falls within what is considered normal classroom instructional practice. Furthermore, participation in the study can in no way affect grades for this or any course, nor can it affect academic or personal standing in any fashion whatsoever.

There are several benefits to be expected from participation in this study. Students currently in the science class may benefit from this note taking style. It could provide a better understanding of the content leading to a successful Regents Exam score. The study will also benefit the teaching staff of the Science Department as we seek ways to improve science instruction.

Participation in this study is voluntary, and students are free to withdraw consent and to discontinue participation in this study at any time without prejudice from the investigator. Please feel free to ask any questions of Mrs. Climenhaga via e-mail, phone, or in person before signing the Informed Consent form and beginning the study, and at any time during the study.

AUTHORIZATION: I have read the above and understand the discomforts, inconvenience and risk of this study. I, ______________________________ *(name of subject),* agree to participate in this research. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed: ____

Parent or Guardian Signature__________________________________

Investigator: ____

Date: ____

APPENDIX B

ADMINISTRATOR APPROVAL FORM

Appendix B

Administrator Approval

I, __________________, Principal of _____________ School, verify that I approve of the classroom research conducted by ______________.

____
(Signed Name, Title of Position)

____
(Printed Name)

____
(Date)

APPENDIX C

NEWTON’S LAWS UNIT

Appendix C

Newton’s Laws Unit

Before treatment, we covered the three Laws from a linear perspective. Treatment began with turning:

Centripetal Force:

Traditional	Inquiry
✓ Derive equation for Centripetal acceleration on board then put in F=ma to get centripetal force	✓ Brainstorm variables that might affect the tension in a string with a mass spinning around one end.
✓ Reinforce equation by attempting to falsify it in the lab.	✓ Test variables in lab and come up with equation for centripetal force from data

Angular Velocity/Angular Acceleration:

Traditional	Inquiry
✓ Derived and defined at the board	✓ Developed the concepts with Experiments in Interactive Physics
✓ Reinforced with a lab using Interactive Physics	

Torque

Traditional	Inquiry
✓ Derived at board	✓ Brainstormed variables that would affect my ability to loosen a top of a jar
✓ Reinforced with a lab using Interactive Physics	✓ Developed experiments to test variables in Interactive Physics
	✓ Used data to build equation

Angular Inertia

Traditional	Inquiry
✓ Derived at board	✓ Brainstormed variables that affect resistance to angular acceleration
✓ Reinforced with a lab using Interactive Physics	✓ Tested variables using Interactive Physics
	✓ Used data from labs to build equation

APPENDIX D

WORK AND ENERGY UNIT

Appendix D

Work and Energy Unit

Work Energy Theorem

Traditional	Inquiry
✓ Defined Work and energy at board	✓ Defined work and kinetic energy at board
✓ Derived theorem from Second Law	✓ Developed a lab to seek connection between the two
✓ Reinforced with lab	✓ Used data to develop theorem

Conservation of Energy

Traditional	Inquiry
✓ Define at board	✓ Investigate in lab
✓ Reinforce in lab	✓ Use data to develop theory

APPENDIX E

ATTITUDE AND COMPREHENSION SURVEY

Appendix E

Survey

Note: this survey is not graded. Its purpose is to help me improve the way I teach. Thank you for taking the time to give thoughtful responses! Your insights are very important to me.

1. Did your class follow an inquiry model or a traditional model for this unit?

_________inquiry
_________traditional

2. Was this model effective? why or why not?

3. Rank how well you understood the lab as you were working.

completely lost ○ ○ ○ ○ ○ ○ ○ Understood every step

4. What was the purpose of the lab?

5. Rank how useful the lab was for helping you to understand ___.

Pointless ○ ○ ○ ○ ○ ○ ○ very helpful

6. What was the most helpful part of the lab?

7. What would have made the lab more helpful?

8. Rank how enjoyable the lab was to complete.

Completely frustrating ○ ○ ○ ○ ○ ○ ○ Very fun

9. Rank your confidence level for understanding what affects _____.

no idea ○ ○ ○ ○ ○ ○ ○ Completely confident

10. Any other thoughts?

APPENDIX F

QUIZZES

Appendix F

Name_____________________

Period_____________________

Centripetal Force Quiz

1. In the Centripetal force lab:

a. Give the dependent variable(s)

b. Give the independent variable(s)

c. Which variables did you and your partner test?

2. Assuming you have a computer some washers, some string, and a force probe, briefly describe how you would get data to test the following relationships (get 3 data pts):

a. mass and centripetal force

b. radius and centripetal force

c. velocity and centripetal force

3. Make two free body diagrams of the washers: one from a bird's eye view, and one from a side view as though the washers are coming towards you. Label forces and circle the centripetal force.

4. If the mass of the washers was .25 kg, their velocity was 2m/s, and the radius the washers revolved around was .50 meters, calculate what the force probe will read in Newtons (show all work and circle your answer).

5. In Interactive physics, you have a 5 kg box attached to a 10 meter long string. The box is revolving in a circle around the other end of the string on a frictionless surface. The tension in the string is 2 Newtons.

a. If you double the length of the string to 20 m what is the new centripetal force_________? Use words, not equations to explain why the centripetal force changed (if it did).

b. What is the velocity of the box with the 20 long string? (show your work and circle your answer)

c. Now the velocity of the box is doubled (string 20 m). What is the new centripetal force________? Use words, not equations to explain why the centripetal force changed (if it did).

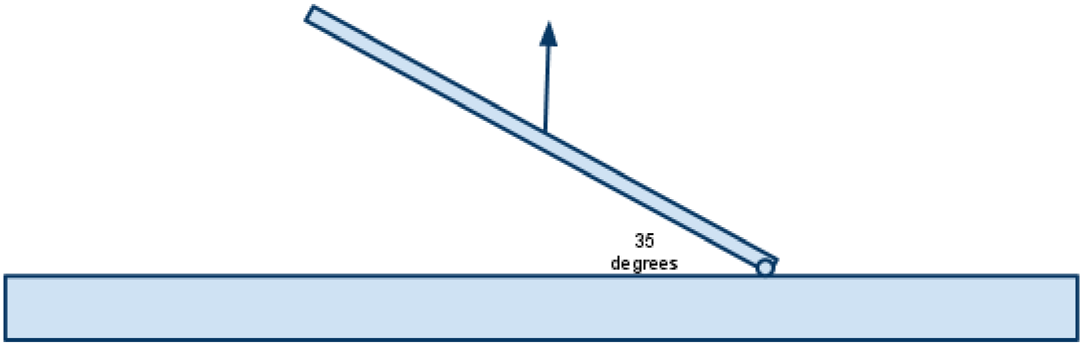
Torque, Center of Mass & Rotational Inertia Quiz

Name________________________

Period_______

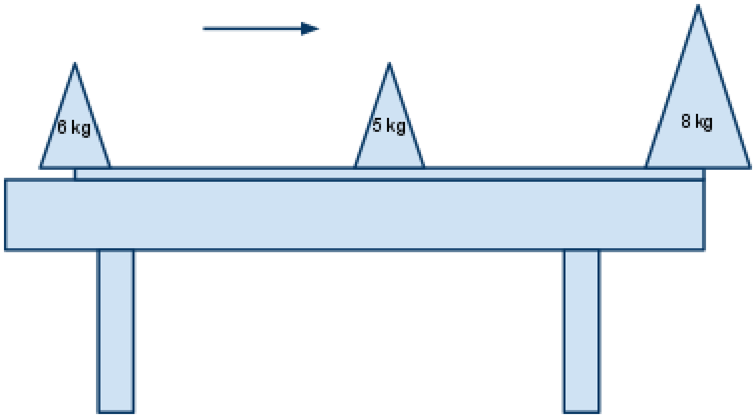
Honor Pledge:

1. A person is asked to hold a 4 meter long 5 kg pipe at an angle of 35 degrees with the ground. The pipe is attached to the ground with a hinge. How much force would be required to hold up the pipe if the force were exerted vertically half way up the pipe as shown below?



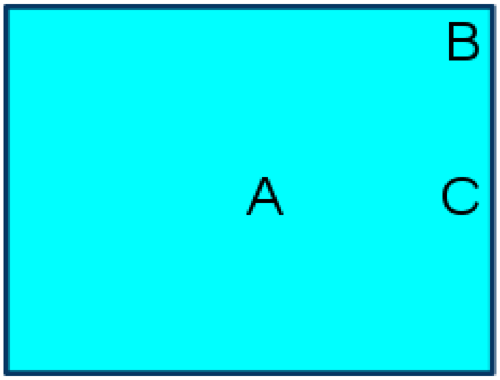
If the person knew more about physics, they could have made their job easier. Draw in a new vector that would require the smallest force to hold up the pipe. Find the magnitude of that force.

2. Three masses are glued to a .5 kg meter stick as shown below (middle mass is in center of meter stick). The meter stick sits on a table. What is the maximum distance the stick could be pushed before the stick and weights would fall off the table? (assume the stick is pushed in the direction of the arrow)



3. You and an opponent are approaching a soccer ball. Each of you wants to push the other away from the ball using your shoulders. Use physics terms to describe the best body position you could have to keep from being pushed over.

4. The box below could be rotated about an axis through letters A,B, or C by a motor that produces a constant torque. Rank the angular accelerations from smallest to largest, explaining your choices.



5. A .5 kg hockey puck is attached to the end of a 2.5 m long massless string. The other end of the string is attached to a peg in the ice. Calculate the puck's rotational inertia around the peg.

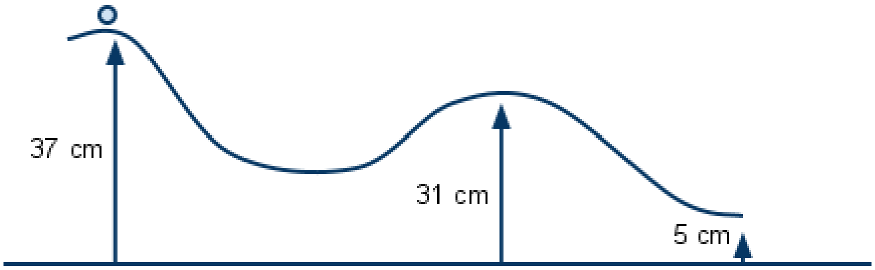
Work Energy Quiz

Name___________________________

Period___________________________

Honor Pledge:

1. A student wants to predict the speed of a 28.1g metal marble at the bottom of a roller coaster ramp diagrammed below. If the marble starts from rest, how fast will the marble move when it reaches the bottom? (ignore air drag, friction, and rotational motion)



2. A 35 kg roller skater wants to roll up a 4 m high ramp to a platform. She has a tow rope to get her up to speed before she gets to the ramp. She starts from rest 25 m from the ramp. She lets go of the tow rope when she reaches the base of the ramp. What is the average force the tow rope must exert in order for the skater to make it up the ramp so she has a speed of 1.2 m/s on the platform (assume friction and air drag are negligible)?

3. A car drives down a road.

a. Explain how friction between the tires and the road could do positive work on the car (use physics terms in your explanation).

b. Explain how friction between the tires and the road could do negative work on the car (use physics terms in your explanation).

4. A car (m = 2000 kg) traveling at 27 m/s climbs a mountain which is 120 meters high. To get to the top the car traverses a winding road that is 1600 meters long (about 1 mile). At the top of the hill the car is traveling at 30 m/s. During the trip the car encounters an average force from the air of 30 N. How much work does the car’s engine do during the trip.

APPENDIX G

LAB REPORTS

Appendix G

Lab Report Instructions

All lab reports are to be turned in electronically as a Microsoft Word document. They should include the following sections:

1. Purpose: Tells the reader what you tested in the lab. It specifically mentions all variables tested. It gives the reader a question.

2. Procedure: Describes to the reader how to get the data. The instructions are detailed enough so that another ninth grade physics student could complete the lab and get the same data. Procedure assumes the reader is familiar with the equipment.

3. Data: All measurements are recorded in an organized manner. Tables are used where appropriate and units are used on all measurements.

4. Analysis: Tells the reader how to use the data to come to a conclusion. Examples of calculations are included. Graphs are used where appropriate.

5. Sources of Error: All sources of error are listed and explained. Percent error is calculated.

6. Conclusion: Uses data from analysis to answer the question.

APPENDIX H

INFORMAL ETHNOGRAPHIC INTERVIEW

Appendix H
Informal Ethnographic Interview

1. In your own words, what is __ (the topic we are studying).

2. How is this concept useful outside of physics class?

3. I am going to give you a problem and I want you to walk me through the steps you go through as you solve the problem.

4. How do you feel about the (inquiry/traditional) teaching style we have used for this topic?

4. Which do you like more, traditional or inquiry?

5. any helpful thoughts or observations?

6. Thank you!