GUIDED INQUIRY USING THE 5E INSTRUCTIONAL MODEL

WITH HIGH SCHOOL PHYSICS


by


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## STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

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TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ABSTRACT

My project focused on the effectiveness of guided inquiry strategies to help students learn physics. Physics is a subject which lends itself to inquiry teaching, where students discover the answers to scientific questions rather than being told the answer. The study involved twelve high school physics students.

Student interviews, surveys, and conceptual assessments were used to gauge the effectiveness of this teaching strategy. I collected data and compared two treatment units (inquiry) to a nontreatment unit (traditional). Results were expressed as a percent change in student learning. I also investigated the effect of inquiry teaching on my feelings about teaching, student motivation, and student engagement.

The results of my project indicate that students learn effectively through both inquiry and through traditional teaching. Student understanding results did not differ dramatically between comparison units. However, inquiry may be more engaging for students than traditional lecture style teaching. Some students experienced a decrease in motivation while others students experienced an increase in motivation, possibly indicating the existence of multiple intelligences and different learning styles or a lack of experience with the rigors of inquiry.

My enjoyment of teaching increased when I taught through guided inquiry. I enjoyed seeing the students discover on their own what I was trying to teach them. I also believe that the inquiry style will better prepare students for standardized tests which emphasize process skills versus content knowledge.

INTRODUCTION AND BACKGROUND

Traditional teaching of science conjures images of boring lectures and memorization of facts. That is not a descriptor that I would want a student to use when describing my science class. As a college student of education, I underestimated the difficulty of really getting through to students and getting them interested and excited about the concepts. In a society geared toward instant gratification, it is difficult to keep students' attention. In addition, I have discovered, without their attention, little learning will take place. As I reflected on my teaching, I continued to question how truly to engage the students. In my fifth year of teaching, I feel that I have become an effective teacher, but I would really like to engage my students at a deeper level and get them excited about science and learning.

The wonderful thing about teaching is that the teacher can always reflect on his/her teaching methods and try something new to help improve learning. In order to attempt to engage my students at a deeper level, I have decided to use a guided-inquiry teaching methodology to improve my teaching. Instead of the current verification method (teach students facts and then verify they are true by doing lab experiments), I will operate in reverse, using inquiry (students do labs first, and then we discuss what they learned). I chose the guided-inquiry methodology, specifically the 5E model, after learning about it in professional development conference. The E's stand for engage, explore, explain, elaborate, and evaluate (Lin, 2005). The ideas made sense to me and using inquiry could impact the areas for improvement I was looking for in my teaching. Besides engaging students to ensure they learn, I was also interested in improving student motivation. The guided-inquiry approach also might help in that area, because I believe

student motivation is linked to their engagement level in school. Perhaps by incorporating this new teaching style, I could improve student engagement and motivation, which would also help me feel that I am being more effective in my teaching.

Engaging in a capstone project on one's own teaching is a noble practice. It demonstrates that teachers are committed to improvement and truly have student success as their number one priority. The great thing about the capstone project is that it is not just good for the teacher, but also for the students, parents, and administrators. The students learn more, parents feel better about the school that their children attend, and administrators feel assured they are running a progressive institution.

The project was completed at Park High School (PHS) in Livingston, Montana. PHS is a small town high school of approximately 500 students. The project was completed with a high school physics class of twelve students in the spring of 2012. This section was chosen because physics lends itself to the inquiry method of teaching. Students can discover physics concepts because they can see the concepts at work. Hopefully, if successful, the project will inform me on how well inquiry teaching works for me as an educator. The project focus question is: What are the effects of the 5E guided-inquiry model on students' understanding of physics concepts? The project subquestions are as follows: what are the effects of the 5E guided-inquiry model on students' attitudes and motivation? what are the effects of the 5E guided-inquiry model on students' engagement in class activities? and what are the effects of the 5E guided-inquiry model on my enjoyment and perceptions about teaching?

My project team consists of Jewel Reuter, capstone advisor; Peggy Taylor, MSSE faculty member, Jerry Nelson, Casper College science reader, Randy Mogen, science teacher at Park High, former MSSE graduate, and Natalie Davis, science teacher at Park High, former MSSE graduate.

## CONCEPTUAL FRAMEWORK

Using the inquiry teaching to improve student learning is nothing new in science education. Incorporating inquiry into the science classroom has been around for the last one hundred years. The earliest recommendation of using inquiry in the science classroom came from Dewey in 1910, when he reported that there was too much emphasis on the learning of facts and not enough critical thinking and understanding in science education (Barrow, 2006). Use of inquiry in science teaching has many forms, but the rationale for the use of inquiry generally follows two forms: the scientific and constructivist rationales for inquiry teaching (Furtak, 2006). The scientific rationale affirms that students learn science best by actually doing it in a fashion similar to what scientists do professionally (Furtak, 2006). This would be following the scientific method through experimentation. The constructivist rationale reports that students learn best by constructing their own knowledge, thereby, taking ownership of it (Furtak, 2006). This means that students "discover" science for themselves and build their knowledge base. My capstone project is grounded in these educational theories.

Inquiry as a teaching methodology can be summed up as "data before construct" (Jones, 2010). This is exactly what practicing scientists actually do, which is, asking scientific questions, collecting data, and formulating conclusions. If students are actually

doing science, they see the learning as being more relevant to their lives. The inquiry process also helps students learn the process of doing science, which can be applied to any scientific topic.

The inquiry teaching methodology has many forms from open inquiry to traditional direct instruction. Because of the many varieties of inquiry, there has been confusion about what exactly defines inquiry teaching (Barrow, 2006). The focus of this project, guided-inquiry, falls somewhere between the two extremes (Furtak, 2006). In an open-inquiry setting, students generate the question and design experiments to answer those questions. In guided-inquiry, the question and the experiment are provided as a framework in which the student may do the exploring. This is done to help expedite the process and to keep students on track with respect to state science standards. Most often teachers will structure the activity so that these standards are being met. Another facet of the guided-inquiry model is that students are not told the answers to the questions before them. The teacher is simply there as a guide to help students, but not give away the answers (Jones, 2010). If the teacher gives the answers, then the constructivist rationale for the guided-inquiry model becomes null. Furtak (2006) explains the work by Edwards that the knowledge that the students gain in middle school science from going through this process is more full and complete if they find the answers on their own, rather than being told the answers.

Guided-inquiry is not without its flaws, however. For the model to run smoothly, the teacher must withhold answers (Furtak, 2006). It has been shown that students will press the teacher over and over for the correct answer. It becomes hard for a teacher to continually justify why he/she is withholding something that is known. Many students

are familiar with direct instruction where the answer is known in advance and if the students do not see what they should be seeing then something must be wrong. Here the students must be confident enough in their observation and experimentation that they can be confident about their conclusions (Furtak, 2006). A question to ponder is, how successful inquiry would be if students did not have excellent lab skills. Another issue with guided-inquiry has been referred to as the *teacher's dilemma* (Furtak, 2006). The issue here concerns how experimental, student-centered learning can truly exist with the requirement that they discover what they are supposed to. In an ideal setting, student exploration could take them into a completely new study than what is supposed to be taught. Guided inquiry is a compromise between this ideal setting and the reality we live in with standards and assessments. In order to alleviate this dilemma, the use of guiding questions can be used (Jones, 2010).

No one likes to compromise, so why not attempt open inquiry? Open inquiry, which has the students generate the research question, truly allows for intellectual flexibility and critical thinking skills to flourish (Sadeh, 2009). Actually, a study done by Sadeh comes to the conclusion that although there are some good results from open inquiry, guided inquiry actually may be better for students in high school biology. The results of this study suggest that when comparing guided-inquiry to open inquiry, students actually learned more of the content through the guided-inquiry process as well as well as experiencing greater enjoyment in learning. Through the open-inquiry model students learned more about the procedure of doing science. Since my goal is to improve student learning of physics content, I have chosen to incorporate a guided-inquiry model.

Specifically, I used the 5E instructional model. The five E's stand for engage, explore, explain, expand, and evaluate. In the *engage* step, teachers try to elicit prior knowledge and get the students interested in the topic of study (Gejda & LaRocco, 2006). Often a demonstration without an explanation is performed. This "sets the hook" in the students, hopefully drawing out their instinctual curiosity. The key point is that the students will find the explanation for themselves through the next stage of the model. Other methods of engaging can be to use KWL charts (what I know, want to find out, and learned) or the use of questions to draw out of the students, personal experiences. The next step (*explore*) is at the heart of the inquiry model. Here, no direct instruction takes place. The teacher is seen as a consultant (Trowbridge & Bybee, 1990), to help the students along through the process. Students will be given a question and materials, as well as directions about what to do, but the students must make sense of it all. Through experimentation and observations, they form conclusions about what is happening. This hands-on step is the key ingredient in the teaching model. Students should come away from this step with some hypotheses that they have formulated. Something to remember here is that it is acceptable to have a hypothesis that the data contradicts. If the conclusions that the students have formed were based on faulty lab work, they will be required to go back and revisit the experiment (Jones, 2010). The next step (*explain*) is where the students analyze and synthesize their ideas (Gejda & LaRocco, 2006). Here students may build models, clarify concepts, and develop explanations. The teacher at this point may give formal definitions, labels, and explanations (Gejda & LaRocco, 2006). The fourth phase, the *elaborate* phase, requires students to take what they have learned from the first three steps and apply it to new situations, thereby, getting to higher

levels of thinking in Bloom's taxonomy.  The last phase is *evaluation*.  In reality this phase should be embedded in each phase as formative assessment.

Many studies have been completed recently regarding the effectiveness of inquiry style teaching in the high school classroom.  Most of the results seem to come to similar conclusions.  A study done by Peter Rust in 2011 on his high school physics class showed that his students' problem solving abilities increased and students demonstrated increases in conceptual understanding (Rust, 2011).  Rust also mentioned that he thought students actually preferred traditional labs to inquiry based labs because they were easier (Rust, 2011).  As far as engagement goes, this same study showed that students were more engaged (Rust, 2011).  The mention of students not enjoying the inquiry labs was a concern, and also supported by an additional study completed by Grant on her high school chemistry class that found students expressed frustration during the inquiry labs (Grant, 2011).  No teaching methodology is without flaws, and perhaps student enjoyment is one of the drawbacks of using inquiry.  However, the vast literature which exists about the gains in student learning and students' ability to retain information may be worth the cost (Madden, 2011).

Other studies designed to investigate the effectiveness of inquiry teaching include one completed by Haury (1993), as cited by Anderson (2002), which indicated that increases in conceptual understanding as well as an improved attitude towards science took place.  Some studies indicated results that are not necessarily as definitive as Haury's study (Anderson, 2002).  Perhaps this is due to the extremely broad definition of inquiry and the varying ways teachers implement it.  Another study mentioned by Anderson (2002) is one by Lott (1983), whose results showed only small gains made by

students through the use of inquiry. On the other hand, the study done by Shymanski, Kyle, and Alport (1983), as cited by Anderson (2002), showed that students' cognitive achievement, process skills, and attitudes towards science improved. It appears that there is some uncertainty regarding the effectiveness of inquiry, but also if done correctly, may lead to increases in student understanding.

Studies that focused specifically on the 5E learning model show positive results with respect to student learning. One such study completed by Tural, Akdenic, and Alev (2010) who investigated the effects of using the 5E model on student teachers' understanding of weightlessness found that student learning improved through the use of inquiry. These student teachers showed an improvement in their understanding of weightlessness that went beyond the textbook definition (Tural, Akdenic, & Alev, 2010). Another study completed by Lin, Peng, and Wu (2005) investigated the effect of the 5E model on fourth graders' knowledge, understanding levels, and also the students' perceptions about science learning. The results of this study showed that the fourth graders improved in both knowledge and understanding through the use of the 5E model. Also, the students reported that they enjoyed learning though the inquiry style (Lin, Peng & Wu, 2005).

The use of inquiry also has been documented to have an impact on how the teacher feels about using the methodology. Teachers at the secondary level who have successfully incorporated inquiry based strategies for student learning have reported a sense of accomplishment and pleasure (Mule, 2006). There does appear to be a time however, during the initial phases of implementation, that inquiry is frustrating, and teachers have reported apprehension about using a new methodology (Mule, 2006). Once

confidence is gained, however, teachers do seem to enjoy using inquiry (Mule, 2006). A

study completed by Stricklyn in 2011 on her sixth grade science class investigated how

she felt about using the 5E model in her teaching (Stricklyn, 2011). She reports that

using the 5E model was exciting due to the increase in student engagement which she

observed (Stricklyn, 2011). There was one downside to using the 5E model however,

which was that it took more time to complete each unit, but perhaps having a closer

connection with students is well worth it (Stricklyn, 2011).

Interestingly, as wonderful as this methodology sounds, it is not without

obstacles. Teachers report the following as the main reasons why using inquiry is

undesirable: lack of time and resources, topics are hard to teach using inquiry, and the

problem with content coverage (Gejda & LaRocco, 2006).

Another factor that I will examine in this study is how this methodology affects

student motivation. There has been much research on student motivation and all of it

says that motivation affects student learning. Will the use of the 5Es also increase

motivation to learn? In science, student engagement is critical to rekindle the students'

inherent curiosity about the natural world (Patrick & Yoon, 2004). If their curiosity is

sparked, so will their motivation to learn increase. One insight from a study done by

Patrick and Yoon, suggests that students are most motivated to learn when they study

topics that are of interest to them. Unfortunately, every topic might not be interesting to

every student, but good teachers can make just about any topic interesting if they are

creative enough. There is a definite link between the hands on aspect of teaching inquiry

and student engagement which leads to motivation. One obstacle is that students may

just give up until they are told the right answer (Patrick & Yoon, 2004). This would be

an example of students engaging in performance avoidance, typified by lack of persistence. In the study done by Patrick & Yoon (2004) looking at how inquiry affected student motivation, it did show that all students reported increased motivation to learn using this method.

Using inquiry in the science classroom has been shown to have positive effects on student learning and engagement, however, mixed results concerning student motivation have been documented. The constructivist rationale and the scientific rationale both support the use of inquiry in the science classroom. Engagement of students is critical for student motivation. Motivation and learning are inextricably intertwined. The goal of this study was to apply the guided-inquiry model, specifically using the 5Es to increase student understanding of physics. The secondary goal of this study was to increase student engagement and motivation.

## METHODOLOGY

### Project Treatment

In order to address the project questions, the 5E learning model was used to teach two treatment units after a normal unit of study was completed. Student gains between the treatment and nontreatment units were then compared. The nontreatment unit was taught using my normal teaching style of lecture followed by a lab, also referred to as traditional teaching. The nontreatment unit covered fluid dynamics which was followed by treatment units on sound and light. Preassessments concerning student motivation and engagement were given at the start of the project and preassessments for physics concepts were given at the start of each unit. After implementation and data collection, the

effectiveness of the treatment was assessed by comparing results from the nontreatment unit to the treatment units.

The nontreatment unit was taught first and the learning cycle began with a demonstration. In this traditionally taught unit, a direct explanation of the phenomenon took place after the demonstration. Students were given a chance to attempt to explain on their own before the answer was given by the teacher. In the nontreatment unit, the next teaching step after the demonstration was to present unit material through direct instruction and lecture related to the demonstration. Students took notes from the board and homework reading and questions were assigned, which directly related to the content of the day. Students then moved into the lab to verify the content they have learned. Often this type of lab included some type of percent error calculation. The next step in the traditional method was a discussion of the lab results and a final verification of the science content at hand. At this point a formative quiz was given before moving on to new content. If the results of the formative quiz indicated lack of student understanding, re-teaching took place. The process was repeated for new topics in the same unit and eventually a summative test was administered.

The 5E model stands for Engage, Explore, Explain, Elaborate, and Evaluate. This is a step by step model of inquiry instruction. The treatment units began with an *engage* activity, which was a demonstration or attention getter to "hook the students" and capture their attention. Students were not told the explanation of the natural phenomenon that took place in order to stimulate their curiosity and lead them into laboratory exploration where they attempt to understand the topic.

After the initial *engage* section, students launched into a guided-inquiry activity in order to understand and *explore* the topic. Students engaged in hands on activities by following guiding questions and instructions. For example, in the treatment unit on sound, students experimented with slinkies and ropes to model the different types of waves and interference between waves. The instructions made sure the students were moving in a direction towards the material specified in the curriculum. The teacher did not tell students if their answers were right or wrong, only helped facilitate the activities. The reason for this was to have students generate their own conclusions based on scientific observation. Often the *explore* section of the inquiry model took several days.

The *explain* portion of the treatment units began with a discussion about the results students observed in the laboratory. After the discussion, the teacher pointed out incorrect conclusions and redirected students back to the lab for additional data collection. Once all scientific observations were sound, the teacher explained to the class the interpretation of those results relating to the topic of study. Students at this point formally wrote down definitions and main ideas from the topic as well as a summary about what they learned. If necessary, students were able to use their books as resources at this point.

With the 5E model, the *elaborate* section took place next. The teacher *elaborated* about the concept and discussed real world applications of the concepts. Also the teacher gave the students example problems on the board. Homework questions and reading assignments took place at this point. Homework was then discussed and a formative quiz given the following day.

Based upon the results of the quiz, which was not graded, the teacher would either go back and re-teach critical concepts or move towards a new topic. After all topics in the unit had been covered, a review and summative assessment took place. This phase of the treatment unit would be the *evaluate* section, the final stage of the 5 E model.

## Data Collection Instruments

The study was completed at Park High school in the small town of Livingston, Montana. Livingston has a population of around 7,000 people and is surrounded by mountains. The students in the study were in one section of 11th and 12th grade physics. The students in this class were all high achievers. Because physics is an elective class, all students signed up for the class based on interest in the subject area. There were twelve students in the classroom. This class was chosen because I feel that physics lends itself to inquiry style teaching. My current teaching methodology is effective but I am always looking for ways to improve my professional practice.

In order to assess the effectiveness of the treatment, numerous data collection techniques were employed to compare the change in students' attitudes and performance. Table 1 is a triangulation matrix, describing the methods used, which addressed each question for the project.

Table 1
*Data Triangulation Matrix*

| Project Questions | Data source 1 | Data source 2 | Data source 3 |
|---|---|---|---|
| Student understanding of physics concepts | preunit and postunit assessments for nontreatment and treatment units | Pre and postproject student perception of understanding of concepts survey | Pre and postproject understanding of concepts interview |
| Student motivation | Motivation interviews completed at end of project | Motivation attitude scales completed at end of project | Student lab partner motivation ratings for nontreatment and treatment units |
| Personal enjoyment and perceptions | Field notes during labs for treatment and nontreatment units | Reflections weekly | Self-assessment at end of project |
| Student engagement | Tally sheet during treatment and nontreatment labs | Pretreatment and posttreatment survey | Field notes completed by colleague teacher during both units |

The data collected above include both quantitative and qualitative data in order to adequately address the project questions. 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.

For the main project question on student understanding of science concepts, a preunit and postunit understanding of concepts assessment was used to gauge the learning that has occurred from the start of the unit to its conclusion (Appendices J, K, and L). The short-response questions in the pre and postunit conceptual assessments were designed to make sure students could not guess and get the correct response. Student responses were scored as not proficient, nearing proficiency, proficient, and advanced.

Each of these categories was assigned a point value and all responses added to calculate

the overall score for the assessment.  The increase in student understanding was

demonstrated by comparing the percent change of students' understanding of concepts

from the preunit to the postunit assessment scores.  The percent change, which

represented student learning, was compared between all three units.

A student perception of understanding of concepts assessment was also given to

determine how well the treatment unit helped in student understanding.  The rationale for

the use of this assessment was that sometimes students' perceptions of understanding

may differ from that of the teacher. Students completed the survey in Appendix M before

each unit and after, and changes in student perceptions were qualitatively compiled.

Responses were scored from one to four with number one representing minimal

understanding, and number four representing an expert level of understanding.

The last tool to assess understanding of concepts was pre and postunit interviews

with students about the concepts that they learned (Appendix N).  The interviews asked

students how well they understood the concepts presented with respect to the teaching

methodology.  Four students were selected to complete the interviews on understanding

of physics concepts.  The responses to the interviews completed for the treatment units

were compared qualitatively to the interviews for the nontreatment unit.

The student motivation subquestion data collection consisted of a series of

interviews as well as attitude scales and ratings completed after each unit was taught

(Appendices G, H, and I).  The student interview was completed on six students and

assessed how well the teaching methodology affected students' motivation to learn. I

scored their responses on a scale from one to four with number one being that motivation was decreased by the teaching style and four being that motivation was improved by the teaching style. Each student was a high achieving student because of the elective nature of the class. Each student was personally interviewed at the end of each unit using leading questions to assess how the treatment versus nontreatment units affected their motivation towards learning.  Each student in the class also completed an attitude scale using Likert measurements about how they felt learning with the traditional method compared to the treatment method.  The third tool to measure student motivation was student ratings of their lab partners.  Students gave their partner a score on motivation for the treatment labs and the nontreatment labs.  I had students rate their partners on a scale of one to four, number one being minimal motivation displayed, and number four being highly motivated.

My personal enjoyment and perceptions subquestion was assessed by taking field notes as the inquiry process unfolded (Appendix E).  At the end of the day, I went back through the notes and reflected on how the day progressed (Appendix F).  At that point, I wrote about my perceptions of the project and noted things that went well or not.  Finally, I completed a self-assessment (Appendix D) at the end of each unit.  These were scored quizzes with questions relating to my enjoyment level.  The point values were tallied to reveal the method which I found most satisfying to teach.

Student engagement was measured primarily by the use of a tally sheet (Appendix B), with numbers representing each student.  Each student received a number which correlated to a level of engagement, based on the rationale presented in Appendix B. The tally sheet was used during the treatment and nontreatment labs.  Field notes were

also taken by a teacher colleague for specific students about their level of engagement during the lecture and during the discussion (Appendix C).  This teacher came in to observe the engagement at these times because I was lecturing or leading the discussion. He watched four students and recorded their level of engagement for a ten minute period of time, and also recorded some observations.  Finally, students completed one last survey about how much they felt engaged in the learning activities for the treatment unit and the nontreatment unit. (Appendix A).

Once these data were collected, I analyzed the quantitative data to look for improvement between the two units.  Qualitative data such as field notes and reflections were read at the end of each unit to draw meaningful conclusions.  These conclusions were documented.  Unbiased conclusions were drawn from the data in order to inform myself about whether or not to continue with the 5E model.

## DATA AND ANALYSIS

In order to answer my project questions, I collected data during a normal teaching unit on fluid dynamics, which represented the nontreatment unit, and also from two treatment units on sound and light where I taught primarily through an inquiry based methodology.  The main project question on the effects of student understanding levels was addressed by collecting three different types of data.  These data include pre and postunit assessments, student perceptions of understanding, and student understanding interviews.  Students were given a pre and postunit assessment for each unit of study. Students were also interviewed at the beginning of the project and the end of the project. Finally, students completed a self-assessment of how much they perceived to know about

the topic at the start of the project and again at its completion. By calculating a percent

change in student learning with each assessment tool, conclusions were drawn which

compared the effectiveness of the two units in achieving student understanding. The

preunit and postunit assessment data for the three units are displayed below in Table 2.

Table 2
*Average Scores of Unit Preassessments and Postassessments (N=11)*

| Unit Data | Nontreatment Unit Points Earned (16 possible) | Treatment Unit1 Points Earned (18 possible) | Treatment Unit 2 Points Earned (18 possible) |
|---|---|---|---|
| Preassessment | 2.45 | 10.54 | 3.18 |
| Postassessment | 15.18 | 17.36 | 16.16 |
| Percent Change | 519% | 64.7% | 414% |

There were large increases in students' understanding during the nontreatment

unit on fluid dynamics. This may be due to the fact that students were unfamiliar with

the topic and most scored low on the preassessment. Students were also familiar with

learning through lecture and may have been taking time to get accustomed to the 5E

learning model.

Average percent change for the sound unit was much less than the nontreatment

unit. This is the case because students had more prior knowledge about sound and, thus,

were not able to demonstrate the large learning gains that they had during the fluids unit.

In both the sound and fluids units, students did very well on the postunit assessments.

Average percent change in the second treatment unit was remarkably different

from the first, most likely because students were not as familiar with optics. Once again,

scores were high on the light postassessment, but lower than the previous two units. A

comparison of average percent change between the three units is shown below in Figure

1.
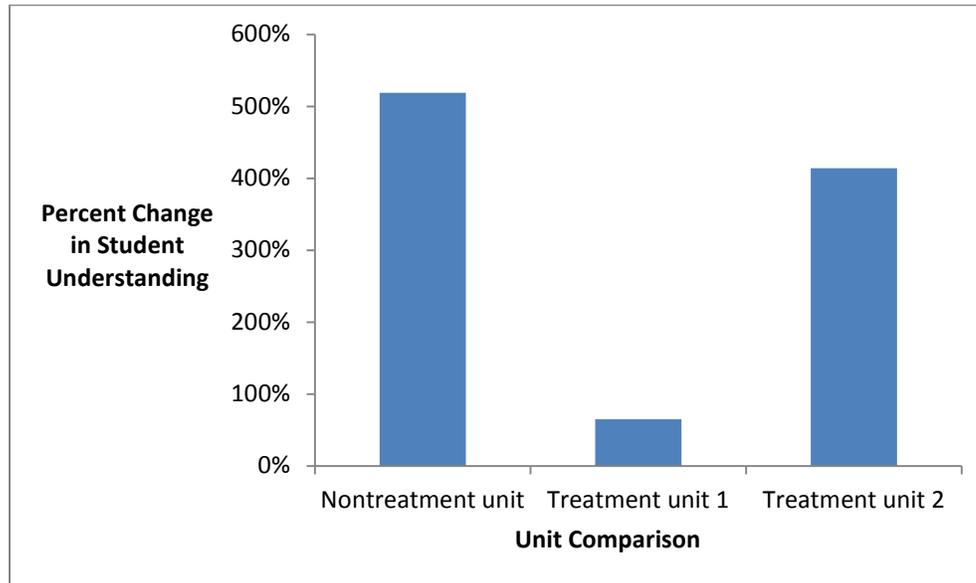


*Figure 1.* Comparison of average percent change for student understanding between units, (*N*=11).

The data indicated that gains in student understanding, as shown by percent

change, were greatest for the nontreatment unit. However, both treatment units show

evidence of student learning. The treatment unit on sound showed the smallest percent

change in student learning because students had the greatest amount of prior knowledge

for that unit and they were getting accustomed to the 5E learning strategies. These data

for the treatment units indicate no particular benefit to student understanding when

compared to the nontreatment.

These data do indicate that both teaching methodologies were successful at

helping students to learn the material due to the fact all postunit assessment scores were

very high.  The class average for all postassessment was in the A range. There were not

many options for students to do much better. This is shown below in Table 3.

Table 3
*Student Scores on Postassessments Expressed as a Percent (N=12)*

| Nontreatment (Fluids) Postassessment Average Score as a Percent | Treatment 1 (Sound) Postassessment Average Score as a Percent | Treatment 2 (Light) Postassessment Average Score as a Percent |
|---|---|---|
| 94.8% | 96.4% | 89.7% |

The next data collection instrument to report on student understanding was a

survey students took about their perceptions of how much they actually understood the

material.  All students were given the survey at the beginning of the project and once

again at completion.  The survey asked them how well they perceived to understand each

unit before and after the unit was taught.  The data are displayed in Table 4.

Table 4
*Student Survey Perceptions of Understanding Average (N=10)*

| Unit Data | Nontreatment | Treatment 1 | Treatment 2 |
|---|---|---|---|
| Preassessment | 1.1 | 1.8 | 1.8 |
| Postassessment | 2.5 | 2.6 | 2.7 |
| Percent Change | 127% | 44% | 50% |

*Note.* 4=Student is an expert and 1= Very little understanding.

The data show that students gained more understanding through the traditional

teaching unit on fluids than the treatment units.  However, this may be due to the fact that

many students did not feel that they knew much about fluids prior to starting when

compared to the treatment units.  These data are also shown again as Figure 2 below.
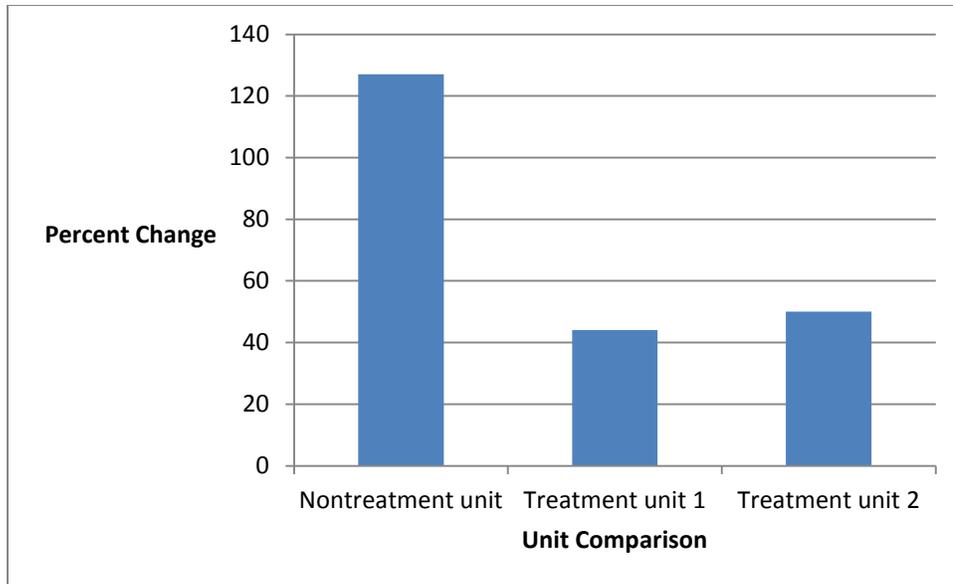
*Figure 2.* Average percent change for student perceptions of understanding, (*N*=10).

The last data used to assess student understanding was preunit and post unit

interviews conducted with four students.  A summary of the data collected is shown

below in Table 5.

Table 5
*Scored Student Interview Questions about Understanding Concepts Average (N=4)*

| Unit Data | Nontreatment | Treatment 1 | Treatment 2 |
|---|---|---|---|
| Preunit | 2.25 | 1 | 1.25 |
| Postunit | 3.75 | 3.25 | 4 |
| Percent Change | 66% | 225% | 275% |

*Note*. 4=excellent understanding and 1=minimal understanding.

Interestingly, this tool showed that the treatment units helped students understand

more than the nontreatment unit. The reason for this was that most students had some

prior knowledge about fluid pressure at a depth (pgh), which was the topic of the

interview.  Thus it appeared that they gained less knowledge during the nontreatment

unit.  Students were able to answer accurately my other questions pertaining to the

treatment unit topics. A figure comparing the average percent change for each unit is shown below in Figure 3.
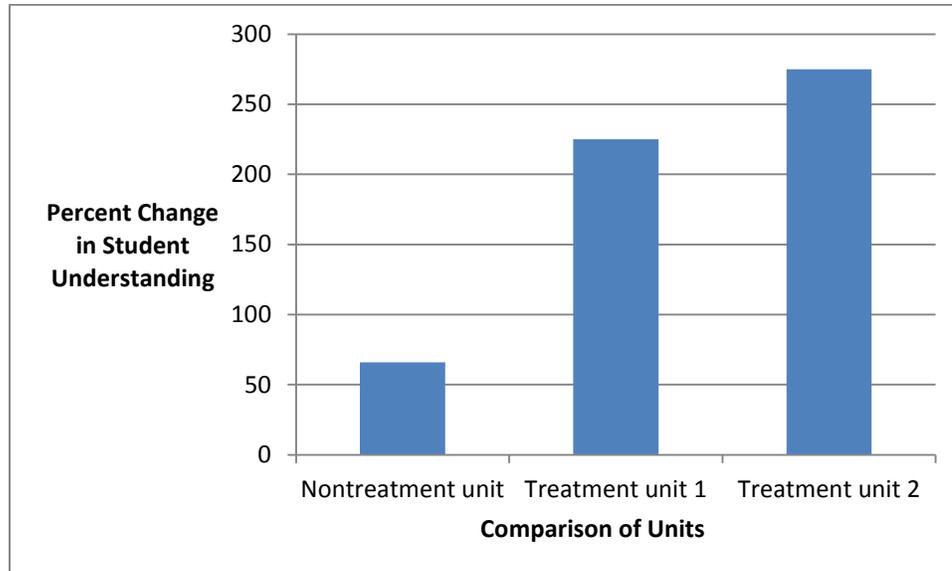


*Figure 3.* Average percent change for the student interviews on understanding of concepts, (*N*=4).

Based on the data collected, it appears that both methods work to increase students understanding. The nontreatment unit did however show larger gains in student understanding. The statistic of percent change seems to be greatly affected by the preunit score, which can be confounded if the students already know the material or if they think they do not know the material. Because of this there is not much improvement the students can show from the pre to postunit assessments. I realize that I made a poor choice for a question on fluids in my student interviews, which is the reason why it looks like student gains are less for that assessment tool. Also that data collection instrument had a small sample size (*N*=4).

The next project question I addressed was how inquiry teaching affects student motivation. I gauged this by interviewing students about how the teaching style affected

their motivation. I also had students fill out an attitude scale where they reported on motivation for both treatment and nontreatment units. Finally, I asked students to rate their lab partners' level of motivation during the inquiry labs and the traditional labs.

The student interviews had a number of questions, but I focused on their responses to questions two and three, which rated incentive tied to inquiry and questions six and eight which rated motivation tied to traditional teaching (Appendix G). A summary of the data is displayed below in Table 6.

Table 6
*Summary of Student Motivation Interview Scores for Targeted Questions (N=6)*

|                                      | Nontreatment | Treatment |
| ------------------------------------ | ------------ | --------- |
| Average motivation interview score   | 2.99         | 2.58      |

*Note.* 4=motivation improved and 1= motivation decreased.

After compiling the data from the motivation interviews, it appeared that students found that traditional style teaching was more motivating than the inquiry based teaching. Reasons for this come from other comments during the interviews such as, "I sometimes feel lost in the inquiry labs." Students expressed that it can be frustrating to have to find out the answer on their own. This may be due to the fact they are accustomed to being "spoon fed" information, but their frustration is noted. Perhaps a high level of frustration means that students are being challenged and forced to use their brains which is a good thing.

Other students expressed that they felt motivated to learn through both styles of labs. Another interesting item gleaned from the interviews is that a few students found inquiry labs more enjoyable and they felt that they learned equally well both ways.

Perhaps the results of this tool indicate less motivation for inquiry because of the demographic of my class. All students were high achieving and perhaps were used to learning in a more traditional format. Thus, they express a decrease in motivation when forced to change.

The attitude scale that was administered about motivation consisted of a series of statements with which the students expressed their level of agreement. A direct number was given for the treatment unit and the nontreatment unit. A summary of the data collected is presented below in Table 7.

Table 7
*Summary of Student Motivation Attitude Scale – Treatment vs. Nontreatment (N=10)*

| Average Nontreatment Score | Average Treatment score |
|---|---|
| 3.2 | 3.1 |

*Note.* 5= high motivation and 1= low motivation.

In this case the students also reported that they felt more motivated during the nontreatment unit than the treatment. This helps to validate that motivation may actually be decreased when inquiry is initially used. Some comments to report for this survey include the fact that getting good grades seem to be very motivating to my students as well the importance of the teacher's ability to motivate. One student said, "Getting good grades is the most important thing for me because that is what my parents want."

The third tool to assess motivation was student ratings of their lab partners. Students would be able to determine better than myself the motivation level of their partners. Results from these ratings are shown below in Table 8.

Table 8

*Partner Motivation Ratings during Lab Activities (N=12)*

| Nontreatment motivation level average | Treatment motivation level average |
|---|---|
| 3.66 | 3.75 |

*Note.* 4= high motivation and 1= low motivation.

The results here were close but in favor of the treatment unit.  This conflicted with the other two tools used to measure student motivation. One thing to notice is that both treatment and nontreatment units showed high levels of motivation.  Perhaps it is difficult to measure someone else's motivation.  Maybe the lab partner perceived that students' hard work indicated motivation, when really the students simply desired completion as mentioned in the comment section of this tool.  In reality those students may have worked hard but not because of the teaching style. The reasons for this may be that students don't like being pushed to find the answer on their own and tend to want to give up instead of struggling to find the answers.

The next subquestion which was analyzed was how inquiry teaching affected student engagement.  In order to answer this question, students were asked to complete an engagement survey, I completed a tally sheet of observations of engagement during labs, and I had a fellow teacher make observations of student engagement during the lecture and discussion days.

The tally sheets had boxes where I made check marks to record my opinion on how engaged the students appeared to be.  These tally sheets were completed during the nontreatment lab and the treatment inquiry labs.  In both situations levels of student

engagement were very high because I was collecting data during hands-on style activities.  The results of the engagement tally sheets are shown below in table 9.

Table 9
*Student Engagement Tally Sheets Data (N=4)*

| Average Nontreatment Engagement | Average Treatment Engagement |
| --- | --- |
| 2.75 | 3 |

*Note.* 1 = low engagement and 3 = high engagement

As I went around the classroom during the inquiry labs, there was a significant amount of engagement, which could be the result of students being forced to focus a bit more than during a traditional style lab.  In order for them to form conclusions on their own, students are engaging higher level thinking skills, and this was evident in my tally sheet data.  I noticed much good discussion in lab groups about the procedure and what their observations meant.  The nontreatment lab was also very engaging as students were bending glass tubing to make manometers.  There was one student who did not seem as engaged by this lab which accounts for the overall lower score for the nontreatment unit with respect to engagement as measured by tally sheets. I think that she did not enjoy the glass bending when the students made manometers.

The next tool which was used to assess student engagement was a survey in which students were also asked to explain their answers. On this survey there were two targeted questions about the treatment unit and two questions which targeted the nontreatment unit, so that a comparison could be made about student engagement.  A summary of the data collected is presented below in table 10.

Table 10
*Student Engagement Survey: Students' Perception of Their Engagement (N=10)*

| Inquiry teaching | Inquiry lab | Treatment engagement average | Traditional lab | Lecture | Nontreatment engagement average |
|---|---|---|---|---|---|
| 3.2 | 3.3 | 3.25 | 2.6 | 3.3 | 2.95 |

*Note.* 1 = low engagement and 5 = high engagement.

These data from the surveys support the idea that inquiry teaching is more engaging to students when compared to traditional lecture and lab teaching. Some students reported that learning on their own was more engaging than traditional methods. One student said, "I wish we could learn this way all the time." It is important to realize that these averages do mask individual learning preferences, because there were multiple students who reported that they felt highly engaged by a dynamic lecture and some that they preferred the inquiry style.

The last data tool to measure student engagement was observations of engagement completed by a colleague science teacher who had a prep period during my physics class and was willing to make some observations. A summary of the data is presented below in Table 11.

Table 11
*Student Engagement observations by colleague teacher (N=4)*

| Nontreatment Average Engagement | Treatment Average Engagement |
|---|---|
| 3 | 2.75 |

*Note.* 1 = low engagement and 4 = high engagement.

In this case it appears that the lecture was more engaging than the discussion, but due to the small sample size and small difference in score, it was not weighed heavily against the other data collection instruments. One reason for this slight increase might be

that I had many real world examples during my fluid dynamics lecture that were visual and meaningful to students.  My observer noted that different students appeared to be engaged in different ways such as one student not taking notes but asking questions and paying attention while another student was so caught up in writing down everything that she did not ask many questions.  There was high engagement during the discussion of the inquiry labs most likely because students wanted to know if they learned the correct thing during the inquiry lab.  One student did not appear to be as engaged as the others during the discussion, which may be due to a negative attitude about inquiry.  This was one of the students who preferred a more traditional teaching format.

The last subquestion investigated in this project was how I felt about teaching using inquiry.  In order to gain some data about this question, I wrote some reflections after each week of teaching.  These reflections were categorized as positive or negative feelings.  At the completion of the project, I also completed a self-assessment where I rated my agreement with a list of statements about personal enjoyment.  The last tool I used was the collection of field notes about my feelings that I took once a week during the labs.  After the completion of my project, I sat down and went back through my reflections, my field notes, and the self-assessment that I took, and I came to some generalizations about how much I enjoyed using inquiry teaching in my classroom.  Data from the self-assessment is displayed in Figure 4.
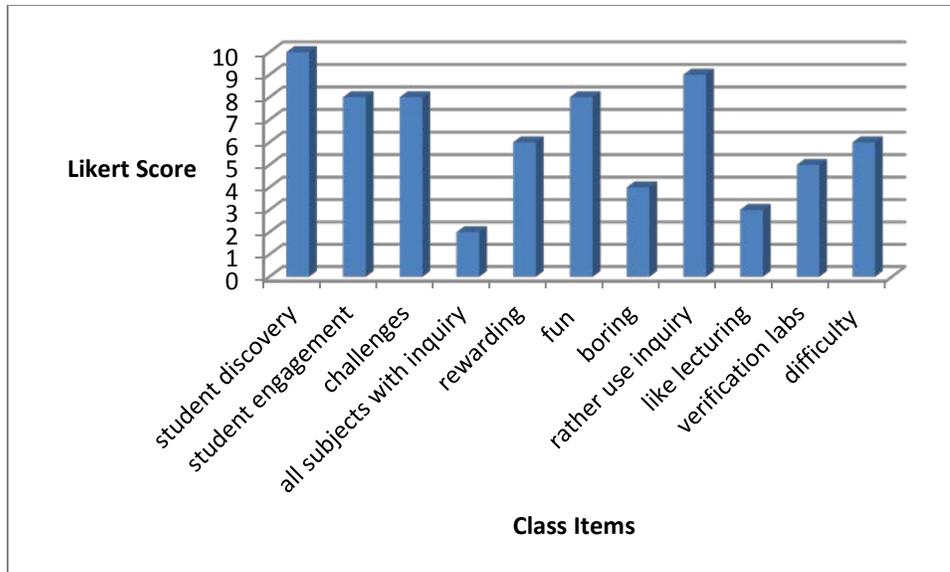
*Figure 4.* Personal enjoyment self-assessment, (*N* = 1).
*Note.* 1 = little enjoyment and 10 = high enjoyment.

One recurring theme was that I was enjoying using the 5E model more than lecture. It was fun to try something new and see good results. I really enjoyed the shift from being a presenter to being a facilitator of learning. It seems to be a less stressful way to teach, because there was less pressure on me to keep students attention. There were some negatives, however. It was hard to collect all of the data that I was trying to collect. I was constantly struggling with student absences and trying to make sure every student completed the surveys. For a couple of the surveys, I did not get 100% completion from students. In my opinion, they grew weary of data collection by the end of the project. On the other hand, it was interesting and exciting to be collecting data about my own teaching and my enjoyment of inquiry teaching.

Another recurring theme was that the inquiry labs were not as engaging to me as a teacher. The labs took time and effort to create and set up, but during the time in class I helped little so they could figure it out on their own. That said, I did help and make sure

they were on the right track, especially with the refraction inquiry lab. Guided-inquiry

operates with a fine line between helping students too much and too little. I think that

they liked the somewhat hands off approach I used, but time passed more slowly for me

than usual. I would say that the inquiry style required more work in planning and less in

actual execution. In the future, I might assist students more or use leading questions to

help them, thereby increasing my level of engagement.

Even though I was not necessarily as active during the inquiry labs, I did enjoy

seeing what the students would do during the labs. I definitely saw them engaging

problem solving skills and using critical thinking which is one of my goals as a teacher.

Sometimes I would ask them questions like, "Are you doing what you know to be good

scientific practice?" Seeing students engage in these activities was rewarding to me as an

educator and that provided a significant amount of personal enjoyment.

Another theme that I found was that I really enjoyed trying something new. I had

used inquiry before, but not to the extent that I did in this project. Being forced out of my

comfort zone was a good thing and I definitely enjoyed trying something new. I think

that is what keeps teaching interesting and enjoyable. I do believe my enjoyment of

teaching would seriously diminish if I do not challenge myself to make needed changes

in the way I teach throughout my career.

A summary of my personal enjoyment with respect to each week is displayed in

Figure 5. The trend here revealed increasing enjoyment overall when teaching the

inquiry units. The first three weeks represent the nontreatment unit and the next six

weeks represent the two treatment units.
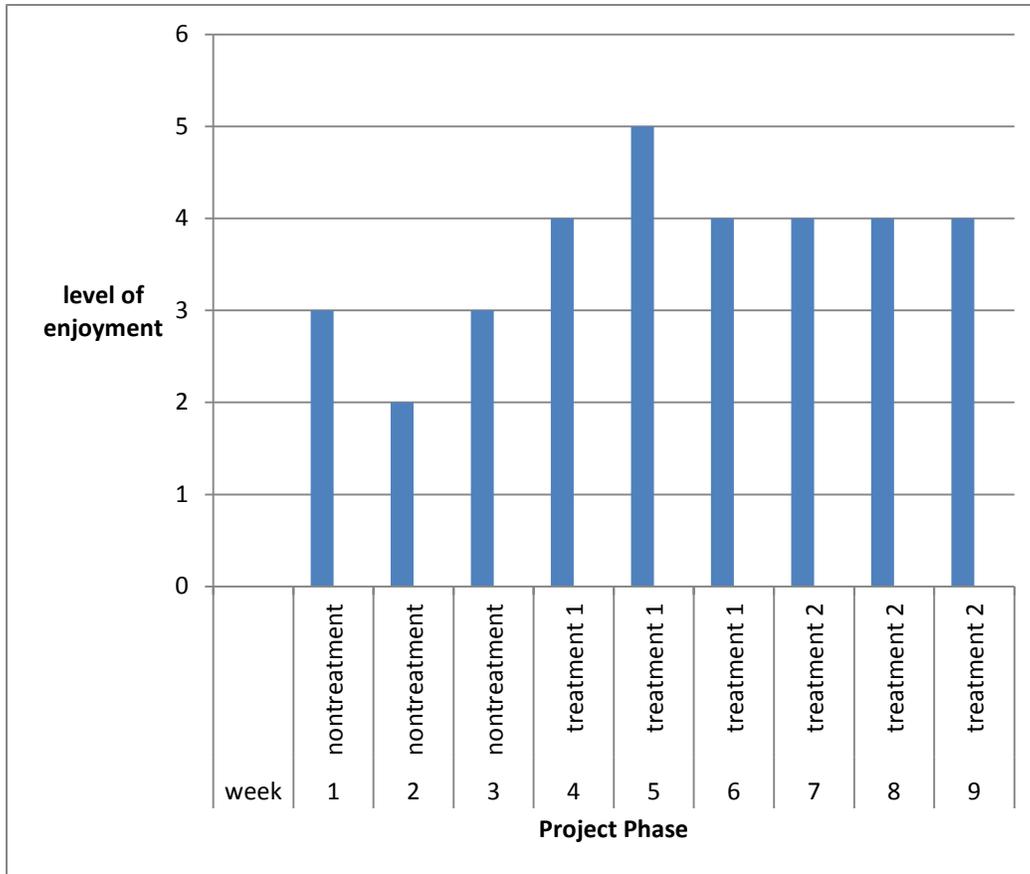
*Figure 5*. Personal enjoyment field notes, (*N* = 1).
*Note.* 1 = little enjoyment and 4 = high enjoyment.

In general, I do find using inquiry to be enjoyable and will do more of it in the future. I liked seeing students being engaged and I also enjoyed teaching differently. In the future a blend of traditional and inquiry seems most prudent because not all students respond the same way to inquiry teaching and change keeps things interesting for me and my students.

## INTERPRETATION AND CONCLUSION

Student understanding of physics concepts was the main measure of inquiry teaching that I was seeking to explore. The percent change between students' scores on the unit preassessments and postassessments showed that students learned slightly more

from the traditional teaching style. This conclusion may not be valid due to the fact that percent change may have been higher in the nontreatment unit because students did not have much prior knowledge about fluids when compared to the two treatment units. In reality, students did very well on all three postunit assessments; the main differences between the units were prior knowledge levels. Ideally one could have three units of equal difficulty that no student was familiar with, and then one could be much more confident in the results of a study like this. In my case the fluid dynamics unit was more difficult than the treatment units which make a comparison between the units difficult. Also, I needed more difficult assessment questions so the students would not be limited in their learning gains. This phenomenon exposes the fact that I was compelled to choose inquiry units that would lend themselves to being taught in that style. In the sound and the light units, students had more knowledge because they experience these things on a daily basis. The fluids unit was a bit more abstract and that is why I chose to teach that unit more traditionally. I have noticed that subjects more conducive to inquiry are probably easier and students are generally more familiar with them. This may not always be the case, but certainly was with this study.

The perception of understanding surveys also supported the result that students gained more in understanding from the nontreatment unit. Once again this gain may be due to the fact that students perceived that they learned the most about a topic they were unfamiliar with or with traditional learning strategies. Interestingly the understanding interview data contradicted the assessments and students' perceptions. These data show that students learned the most through inquiry. The results of this third assessment tool can be negated because of a low sample size and poor choice of interview question

regarding fluids.  In this case most of the students knew previously about the impact of depth on pressure which caused their gains in understanding to be lower than the inquiry units.

In conclusion, regarding student understanding, the results show that both methodologies work to help students learn.  Students demonstrated proficiency in learning for all of the key concepts I was trying to teach.  There is not enough evidence to suggest that one strategy is necessarily better or worse than the other for student understanding.

Student motivation was the next question in this study.  I used student interviews, student surveys, and student ratings of motivation by their lab partner to assess motivation levels.  The results from the data show that, at least for my classroom demographic, the use of inquiry teaching may slightly diminish student motivation.  The results did not indicate huge losses in motivation, but definitely show that students might have been more motivated when learning in a style they are familiar with. In hindsight, I should have combined the motivation tables but did not because of different sample sizes and the assessment tools were given to different students.

Motivation is generally thought of as having a reason to do something.  Many of the motivators for students that were learned from the interviews were things like grades, and the desire to get the work done.  As a teacher, those are not really the answers I want to hear but unfortunately that is the way it is for some students.  If indeed they care only about their grade and not what they actually learn, it makes sense that sticking with something they are used to would be the easiest way to achieve that goal.  Perhaps their

responses would change if inquiry was something students were more familiar with and if students knew how to be successful in that style.

Student engagement was another subquestion focused on in this study. The data shows that the inquiry style may have been slightly more engaging than traditional lecture and lab style. I think that students don't really have much of a choice except to engage when learning through an inquiry based style. In a lecture students can just tune out, but when forced to learn the material through interactive experimentation, students will be either forced to engage or refuse to do the activity. Two of the three data collection instruments supported the idea that engagement was higher through inquiry. The observations from a colleague teacher showed slightly less engagement, but the difference was very small and the sample size also small. Thus I am confident that engagement was slightly increased by the 5 E model.

It is important to realize that the differences between the data of the treatment and the nontreatment units were not monumental. I only observed slight differences between the two for all of the questions I addressed in the project.

There was one additional question that was asked in this study, and it pertained to my personal feelings as teacher when using inquiry as compared to traditional teaching. The bottom line for this question was that I did enjoy teaching through inquiry. I enjoyed it because I liked seeing the students discover things for themselves instead of me just telling them. I also enjoyed the increase in engagement that I observed. I think that inquiry is yet another tool that I will have at my disposal to teach science. It works well

for student learning, and if students become more familiar with it, might not dampen their motivation as much.

A teacher walks on a fine line when it comes to how much help to give students as they explore topics. The location of this line is determined by what style of inquiry the teacher is looking for. In this study I was fairly hands-off, because I wanted the students to find the answers on their own, but in the future I will perhaps give a bit more guidance. This might help decrease the level of frustration and increase the motivation that was observed. It also might increase my level of engagement during class activities. Perhaps then, I could slowly give less guidance and have the students discover more on their own. The shift to an inquiry based classroom should be more gradational than the dramatic shift that I did.

If I had the opportunity to continue this project, there are a few changes that I would recommend. First, I would work very hard to make sure that my preassessments were all the same difficulty. Percent change would have more meaning if the baselines were closer. Second, I would also be interested in how inquiry learning affects student process skills such as critical thinking and problem solving. Really these things might be more important than conceptual understanding. One could assess these cognitive skills though different types of assessment tools than the ones used in this project. I would guess that inquiry would be stronger in those areas as compared to just student learning of content. Third, I would be interested in student enjoyment of learning through inquiry. I looked at motivation and engagement, but I also want to know how much students

actually liked inquiry.  Informally when I asked them this question, it seemed like they preferred the inquiry method over lecture.

I also think that the active learning that took place will help students retain the information for longer periods of time.  I believe this because content that is learned by listening or seeing is forgotten unless students continue to use that knowledge whereas knowledge gained learning by doing lasts much longer.  I would be interested in measuring exactly how substantial this difference might be in a future study.

In order to gather better data in the future, I would try a few different strategies. First, the results of this study could be entirely different for a different population, specifically with respect to motivation for the high achieving students.  Perhaps younger students might learn better though inquiry when science classes are more descriptive and less based on mathematics.  Second, different data collection instruments could have given different results for this study.  For example, the interview questions could have been changed or restructured by difficulty of question.  I would also be interested in how the 5E model would work for other science subject areas like chemistry or biology.

<div align="center">VALUE</div>

This project has forced me to try something new with my teaching, and I view that as the most valuable result of this study.  I learned much about inquiry teaching but am by no means a master of employing it.  I do believe, however, that to stay dynamic in one's teaching is extremely important, otherwise stagnation will set in.  Constantly trying new things is what keeps teaching exciting and enjoyable for me.  I think if I just kept doing what I do now and changing little, I would grow tired of the profession.

I also learned about my students in ways that I did not expect through the completion of this project. They had a chance to tell me how they felt about various topics, and I learned much that I had not intended. One important lesson is that all students learn differently. Though I had already known this, I did not realize the extent to which learning styles varied in my homogenous population of students. Some students loved inquiry while others very much disliked it. What I learned from this was that varying the instructional methodology is important in order to reach all types of learners. Varying the methodology is also important so that I as an educator can remain dynamic in my teaching.

As far as my project questions, the most important piece of data I learned was that inquiry is an effective way to teach students. Students learned slightly more through lecture according to the data, but inquiry was by no means ineffective. Because of this I feel very confident in continuing to use inquiry in my classroom. The main reason I want to continue with inquiry is that I like the high level of engagement and think it emphasizes more of the "process skills" in science. I think that students will be able to do well on standardized tests which emphasize problem solving and critical thinking. I did not measure these things in my project, but in hindsight I should have. I also really enjoyed having one on one time with students which I don't get through traditional teaching. I look forward to perfecting inquiry-based activities and using the 5E model in my physics class and other science courses I may teach in the future.

There is an inherent issue to the use of inquiry, being that it requires more time to complete the learning cycle. Because of this, not all topics can be covered in detail. I

don't view this as much of a problem, however, because students' ability to think and problem solve seems to be at the focus of standardized testing, and those are exactly the areas where inquiry might be better than traditional teaching. If students have the ability to analyze data and draw a meaningful conclusion about it, then it does not always matter if they are not familiar with the content. In reality, content is slowly forgotten unless used, so the skills that students learn and the ability to think become more important if they retain these things for longer.

As my project unfolded this spring, my co-workers in the science department were interested in the results of my study. Some of my colleagues have some experience using inquiry while others rarely employ the strategy. Seeing me try something new might prompt them to attempt using inquiry themselves. Often teachers can get stuck in a rut and sometimes all they need is just a little spark to get them fired up about teaching again. This action research project may provide that spark.

I think that this project also affected the parents of the students involved in the study. I received one email about how a student had come home very excited about what was happening in science class, and she commended me on my efforts and told me, "Keep up the good work!" This student was actually in my Earth Science class, and not in the project section, but I had influenced myself enough to try inquiry activities in my other classes. As a parent I know that I would want my son, when he attends school, to have teachers who desire to improve their teaching skills.

Another aspect to consider was how the completion of this project affected my feeling of professionalism. I would say that I did feel like my level of professionalism

has increased. Completing this capstone is something that I will be proud of and it has renewed my excitement about teaching. I hope to share my findings with my colleagues and I believe that they and will respect me more for my hard work to complete this project.

Future research on inquiry teaching will always involve struggle with the many ways that inquiry teaching is done. For a true scientific study to be completed, a teacher would probably be forced to use some type of premade inquiry curriculum that was somehow standardized as opposed to my study where I created the inquiry activities for my students. I do believe that future studies will show increasing support for moving away from traditional lecturing to more interactive lessons including inquiry, due to changing students. Students today are used to constant stimulation and if we want to reach them where they are, the curriculum must be equally as stimulating.

This paper and the action research project have probably been more valuable to me as a teacher than to the scientific and educational communities at large. My data does not really lead to any dramatic new conclusions, but simply helps underscore that I find inquiry teaching the more effective way to go. I think a longer more detailed study would be needed to report with certainty if inquiry is actually better than traditional teaching methods. I do think it is important, however, that my data does not refute commonly accepted ideas about inquiry teaching. In a sense it serves as another piece of literature to help validate inquiry and help other teachers understand that it is a worthwhile teaching method.

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APPENDICES

<u>APPENDIX A</u>

STUDENT ENGAGEMENT SURVEY

Student Engagement Survey

Rate the following questions using a scale of 1 – 5 (1=very little and 5=very much)

1. Inquiry teaching increased my level of engagement.  Explain.

2. I found the labs more engaging when I discovered the concept on my own. Explain.

3. The teacher has a big impact on my engagement level? Explain.

4. The instructional style used affects my level of engagement.  Explain

5. I am more engaged when I know the answer I am supposed to get.  Explain

6. I want to learn when I am listening to a lecture.  Explain

APPENDIX B

STUDENT ENGAGEMENT TALLY SHEET

Student Engagement Tally Sheet

4 students were selected to be observed for engagement.  Two of the students were A students and two were B students.  Observations occurred during lab activities towards the middle of the period.

Low- Does not appear to be engaged at all, possibly bored.

Average- Student is on task.

High- Student appears to be highly engaged, curious, asking questions and being productive.

| | Level of engagement | | | |
|---|---|---|---|---|
| Student | 1-low | 2- average | 3- high | comments |
| 1 A student | | | | |
| 2A student | | | | |
| 3B student | | | | |
| 4B student | | | | |

APPENDIX C

STUDENT ENGAGEMENT FIELD NOTES

Student Engagement Field Notes

4 students selected were observed by colleague teacher

| Student | Observations of engagement | Time and activity |
|---------|---------------------------|-------------------|
| 1A | | |
| 2A | | |
| 3B | | |
| 4B | | |

APPENDIX D

PERSONAL ENJOYMENT SELF-ASSESSMENT

Personal Enjoyment Self- Assessment

Rate the following items on a scale from 1-10.

10 = completely agree

1 = not at all true

 I enjoy seeing the students discover answers on their own.

I think students enjoy learning through inquiry in my class and this make me happy.

Teaching using inquiry has its challenges.  Explain.

I can teach everything through inquiry.

Teaching using inquiry is more rewarding. Explain.

Teaching using inquiry is more difficult.  Explain.

Teaching using inquiry is more fun.  Explain.

I like going to work using inquiry teaching.

I felt a bit bored just supervising students as they explored.

I would rather teach using inquiry.  Explain.

I like lecturing to the class.

Having the students verify in the lab what we learned in class is enjoyable.

APPENDIX E

PERSONAL ENJOYMENT FIELD NOTES

Personal Enjoyment Field Notes

| week | Rank enjoyment level 1-5, and additional notes |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |

APPENDIX F

PERSONAL ENJOYMENT REFLECTIONS

Personal Enjoyment Reflections

<u>Week 1</u>

Positive

Negative

<u>Week 2</u>

Positive

Negative

<u>Week3</u>

Positive

Negative

<u>Week 4</u>

Positive

Negative

<u>Week 5</u>

Positive

Negative

<u>Week 6</u>

Positive

Negative

<u>Week 7</u>

Positive

Negative

<u>Week 8</u>

Positive

Negative

<u>Week 9</u>

Positive

Negative

APPENDIX G

MOTIVATION INTERVIEW QUESTIONS

Motivation Interview Questions

1.  Please identify and describe factors do you think affect your motivation to do well in school.  Explain.

2.  Did you find the inquiry methodology more or less motivating than the traditional model?  Explain

3.  On a scale from one to ten, how would you rate your enjoyment of the inquiry model?  Explain.

4.  How did this inquiry model compare to any past experience with inquiry you may have had?  Explain.

5.  Do you feel that you understand the content?  Explain.

6.  How well do you like the traditional lecture/lab style of teaching?  Which method is more motivational for you and why?

7.  Do you feel that you understand the content more though the inquiry model or the traditional model?  Explain.

8.  How motivated to learn are you when being lectured to?  Explain.

9.  Does the teaching style used influence your motivation to learn?  Explain.

APPENDIX H

MOTIVATION ATTITUTE SCALE

Motivation Attitude Scale

Answer the following questions with a number value and explain please.

1--- 2 --- 3----4----5

Very little → very much

5-very accurate

4- accurate

3-somewhat accurate

2-statement is mostly inaccurate

1-statement is incorrect.

Rate your motivation to learn when inquiry is used. Explain.

Rate the importance of the teacher with respect to motivation. Explain.

Rate the importance of parents with respect to motivation. Explain.

Rate your motivation to learn when lecture teaching is used. Explain.

Rate your motivation to learn at this school. Explain.

APPENDIX I

MOTIVATION RATINGS BY LAB PARTNERS

Motivation ratings for lab partners

Please rate your lab partners on a scale of 1-4 about the motivation level during the lab today.

1= low motivation

4=high motivation

Please list any reasons why you believe they were or were not motivated.

APPENDIX J

PRE AND POSTASSESSMENT:  FLUIDS

Pre and Postassessment:  Fluids

1.  What force allows humans to breathe? Explain.

2.  Describe the different types of fluid flow.

3.  How does pressure change with depth in a fluid? Explain.

4.  Compare the pressure exerted on a dam with a mile of water behind it to a dam with 3 miles of water behind it.  Both dams are the same height.

5.  Describe one functional application of Pascal's principle. Explain.

6.  What determines the magnitude of the buoyant force?

7.  Describe a real life example which demonstrates how the equation of continuity works.

8.  What happens to pressure in areas with high fluid velocity? Explain.

APPENDIX K

PRE AND POSTASSESSMENT: OPTICS

Pre and Postassessment:  Optics

1.  Explain what it means to have a virtual vs. a real image.

2.  Describe the law of reflection.

3.  How do mirrors focus light and create images?

4.  How do lenses focus light to create images?

5.  Why does light refract?

6.  Explain Snell's law and give an example of how it would be used.

7.  What is total internal reflection and give an example of how it is used.

8.  What is the importance of the focal length for a lens?

9.  Discuss how nearsightedness can occur?

APPENDIX L

PRE AND POSTASSESSMENT:  SOUND

Pre and Postassessment:  Sound

1.  What are some characteristics of waves?

2.  Describe the difference between a longitudinal wave and a transverse wave.

3.  How do waves carry energy?

4.  How can waves interact?

5.  Give a real world example of the phenomenon of resonance.

6.  Discuss the difference between a node and an antinode.

7.  How does the length of a tube affect the pitch that it resonates at?

8.  Explain how the Doppler Effect works.

9.  What are decibels and how do they relate to sound measurement?

APPENDIX M

STUDENT PERCEPTIONS OF UNDERSTANDING OF CONCEPTS SURVEY

Student Perceptions of Understanding

Possible responses:

I am an expert

I know the material

I know some of the material

I know little

1. How well do you think you understand the physics of sound? Explain.


2. How well do you understand the physics of light? Explain.


3. How well do you understand the physics of fluid mechanics? Explain.

<u>APPENDIX N</u>

STUDENT UNDERSTANDING INTERVIEW

Student Understanding Interview

1.  What causes interference and explain how some natural phenomena are the result of this principle?

2.  Why is there more pressure at the bottom of a swimming pool than at the top, and compare the buoyant force for an object near the bottom as opposed to the top?

3.  How are images produced by lenses, and explain how the human eye can see an image?

APPENXIX O

TIMELINE

Timeline

Begin Project January 24

-Administer preunit student understanding of fluids concepts assessment, student perceptions of understanding survey, and complete understanding of concepts interviews.

Unit 1:  Nontreatment Fluids Unit

Jan 24, 25 Lecture: Phases of matter, specific gravity, pressure at a depth:  Magdeburg hemispheres demo

Jan 26- Manometer Lab- student partner motivation ratings, engagement tally sheet

Jan 27- Practice Problems-personal reflections, wrap up Manometer lab

Jan 30- Pascal's principle and buoyancy lecture: Cartesian diver demo

Jan 31- Buoyancy lab

Feb 1 and 2 - Fluid dynamics lecture:  Bernoulli's demo-colleague engagement observations

Feb 3- Paradise Valley Fluid modeling

Feb 6- Fluid modeling, practice test

Feb 7- Discuss practice test

Feb 8- Unit test including post assessment questions- nontreatment postunit assessment

Unit 2: Treatment Sound Unit

Feb 9- Simple Pendulum Demo, Pendulum inquiry lab, treatment 1 preunit assessment

Feb10- Discussion

Feb13- wave motion inquiry activity – engagement tally sheet, partner motivation ratings

Feb 14- Practice Problems Discussion – colleague engagement observations

Feb 15- Reflection and Superposition inquiry lab

Feb 16- Discussion, and check up quiz

Feb 17- Sound waves microphone inquiry lab:  Sound waves and candle demo

Feb 21- Review Practice Problems,

Feb 22- Review, discuss practice test

Feb 23- Test- Sound including Postassessment questions on treatment 1


Unit 3: Treatment Light Unit


Feb 24-Laser reflection demo, Reflection inquiry activity- treatment 2 preassessment

Feb 27- Discussion, homework

Feb 28- Mirror inquiry lab- image formation- partner motivation ratings

Feb 29 – Inquiry lab continued

March 1- Discussion

March2- Refraction inquiry activity-discovering Snell's Law, engagement tally sheet

March 3- Discussion and homework

March 5- Total internal reflection demo, lens demo, lens inquiry activity

March 6- discussion and homework

March 7 – checkup quiz

March 8 – Review

March 9, 10- Test Light including Postassessment questions, postproject motivation survey and motivation interview questions, post project engagement survey, personal enjoyment self-assessment

APPENDIX P

EXAMPLE INQUIRY LESSON:  SOUND

Sound Inquiry Activity

**Wave Properties**

Through this inquiry activity, you will formulate some basic principles about wave behavior and come to some conclusions.  You will need a slinky and a piece of rope as well as a partner. For this activity a wave will be considered a continuous oscillation and a pulse is one disturbance.

Step 1

- Stretch out the slinky between your partner and yourself and make a transverse wave and a longitudinal wave.
- Does one go faster than the other?
- Make a pulse with the slinky and then with the rope.  Which one travels faster? Why do you think this is?
- Make a statement summarizing your observations.

Step 2

- Next pull the rope tight and make a pulse.
- Pull the slinky tight and make a pulse.
- What effect if any does tension have on the speed of a wave on a string?
- If the wave goes faster, does that affect other properties of the wave like frequency and amplitude?

Step 3

- Yesterday we discussed how waves need a medium to propagate though. Brainstorm other types of waves on planet Earth and list them here.

Step 4

- Next we will examine how a wave behaves when it reflects off a boundary.
- Fasten one end of your slinky to a fixed point like the table leg.
- Send a pulse down and observe what the reflected pulse looks like.  You need to make sure that the other end is fixed.  What doe you observe?
- Why do you think this happens?
- Now try the same procedure but have the end of the slinky fixed but free to move up and down.  Use a ring stand to hold the slinky end but make sure that the end can oscillate up and down.
- Are there any differences that the fixed end?

- What is going on here and why?

Step 5

- Now have your partner and yourself send a pulse at the same time. We are going to observe what happens when two pulses interact.
- First try pulses on the same side of the slinky and then try pulses on opposite sides.
- Record your observations. Why is this happening?
- Formulate a statement about how waves can interact.

Step 6

- Tie the string to the slinky and make a pulse which goes from the slinky into the rope. What happens?
- Do the opposite of above, rope to slinky.
- Does the pulse do anything as it goes into the new medium?

At this point, we will reconvene and discuss what we found out. I will explain areas that are confusing.

APPENDIX Q

SAMPLE INQUIRY LESSON: LIGHT

Refraction Inquiry Lab
Explore activity

Step 1

Gather the materials for the lab.

-glass triangle, rectangle and petri dish

-4 pins

-ruler

-cardboard

Step 2

- Start with the glass triangle.

- Place the triangle on the cardboard.

- Place a piece of paper under the glass.

- Place a pin right next to the glass and then repeat on the other side.

- Next place another pin 3 inches from the first pin towards you.

- Look through the glass and move your body until all of the pins line up.

- Have your partner place the last pin on the far side of the triangle so that it

  appears to be in the same line as the other three pins

- Next trace the outline of the triangle and then remove.

- Then use the ruler to draw a line from connecting the pins.

Step 3- Questions

- Describe the shape of the line that you drew which connected the pins.

- If the line you drew represents a ray of light, what happened when the light went into the glass?

- What happened to the ray as it exited the glass?

- Draw a line that is perpendicular to the edge of the outline of the triangle where the ray enters. Use this line called the normal to come to a conclusion about how light behaves when it enters glass and when it exits glass. Use the normal line as a reference for what the ray does.

Step 4

Repeat the same activity with the glass rectangle and then the petri dish filled with water.

- Measure the angle that the light bends exiting the water and the glass.

- Which medium appears to bend light more? Why might this be?

APPENDIX R


PRINCIPAL CONSENT FORM

Dear Gary Kane,

*Requesting permission to undertake research*

As part of my coursework for a Masters degree at Montana State University in science education, I will be completing an action research project this spring. My capstone project is about the effects of inquiry based science teaching methods on student understanding of physics concepts, student motivation, and student engagement. I plan to implement two treatment (inquiry based) units and compare student gains to my normal teaching methods. This project will only affect my one section of physics that I currently teach.

My data collection methods include pre and postunit assessments, student surveys, attitude scales, student interviews, and personal journaling and field notes. None of these assessment tools will present any risk to students, and student participation is voluntary. Each student will provide their assent to participation in the study, and parents will sign a consent form.

If you approve of this research, please sign and return this form at your earliest convenience.

Thank you,

Hermes Lynn

_____

I Gary Kane, principal of Park High school, grant permission for Hermes Lynn to undertake action research in his classroom during the spring of 2012, at Park High school.

_____                    _____

Principal signature                                                        date

APPENDIX S

PARENT CONSENT FORM

Dear Parent/Guardian:

As part of my work to complete a Masters degree in science education from Montana State University, I will be conducting an action research project on the effectiveness of inquiry teaching techniques. Inquiry teaching involves students "discovering" the answers to scientific investigations through laboratory experimentation. This simulates more closely how real scientists work and helps students construct their own knowledge base. Compared to my traditional lecture/lab style of instruction, inquiry can be summed up as experimentation/discussion. I am interested in this teaching methodology because I think that students will learn more and be more motivated to succeed in science.

Throughout the action research project, I will be collecting data to inform myself about how well the inquiry teaching is working. Students will complete surveys, answer interview questions, complete pre and postassessments, be the subject of field notes and observations, and complete attitude scales. Student information will be kept confidential throughout the action research.

If you consent to allow your child to participate, please sign and return this form.

Thank you,

Hermes Lynn

Science teacher Park High School

406-224-1091

HermesLynn@livingston.k12.mt.us

_____ Student Name

**Student Consent Form**

I _____ (student name) agree to participate in data collection for Mr. Lynn's action research project.  I understand that my personal information will be kept confidential and my participation is not the result of coercion of any kind.  The information collected will be for the sole purpose of improving science education at Park High School and the completion of Mr. Lynn's action research project.

_____student signature           _____date

**Parent Consent Form**

I grant permission for _____ (student name) to participate in Mr. Lynn's data collection for his action research project.  I understand that all personal information will be kept confidential and that any results from this project will be used to improve Mr. Lynn's effectiveness as a science teacher.  I also understand that participation is voluntary and will not affect my child's grade or standing in the class.  If you consent to participation in this project, please sign below and return.

Thank you.

_____parent signature           _____date

APPENDIX T

SAMPLE TRADITIONAL FLUIDS LAB

Manometer Lab

Materials:

1. 10 foot section of glass tubing
2. Bunsen burner
3. Water
4. Dye
5. Balloon
6. Pressure gauge

Procedure:

1. Look over the description of a manometer in the textbook.
2. Take your glass tubing and bend at the appropriate spots to make a manometer as shown in your text.  Make sure that the glass is hot before you try to bend it, otherwise it will break.
3. Your task is to measure the pressure in a balloon using the manometer and compare to the measurement by a real pressure gauge.
4. When you put water in your manometer, use some food coloring to help you see the level of the fluid.
5. Calculate the pressure in the balloon and verify the accuracy of your pressure gauge.
6. What is the percent error in your measurement?
7. Draw a diagram of your manometer below.
8. Describe any difficulties you may have had.
9. Remember that pressure at a depth is pgh.