THE IMPACT OF AN INQUIRY BASED APPROACH ON ATTITUDE, MOTIVATION AND ACHIEVEMENT IN A HIGH SCHOOL PHYSICS LABORATORY

by

David J. Bittinger

A Master's Project
Submitted in Partial Fulfillment
Of the Requirements for the Degree of
Master of Science Education
Curriculum and Instruction
Department of Curriculum and Instruction
State University of New York at Fredonia
Fredonia, New York

December 2015

State University of New York at Fredonia
Department of Curriculum and Instruction

CERTIFICATION OF PROJECT WORK

We, the undersigned, certify that this project entitled THE IMPACT OF AN INQUIRY BASED APPROACH ON ATTITUDE, MOTIVATION, AND ACHIEVEMENT IN A HIGH SCHOOL PHYSICS CLASS by DAVID J. BITTINGER, Candidate for the Degree of Master of Science in Education, Curriculum and Instruction, is acceptable in form and content and demonstrates a satisfactory knowledge of the field covered by this project.

[redacted]
Master's Project Advisor
Dr. Mahoney Course Instructor
Department of Language Learning and Leadership

12/12/15
Date

[redacted]
Department Chair
Dr. Robert Dahlgren
Department of Curriculum and Instruction

1/04/2016
Date

[redacted]
Dean Christine Givner
College of Education
At SUNY Fredonia

1/5/2016
Date

Abstract

The purpose of this study was to examine the effectiveness of an inquiry style laboratory on attitude, achievement and motivation in a high school physics class in Western New York. A quasi-experimental action research design was used to investigate student attitude, motivation, and achievement when exposed to inquiry style labs. The researcher investigated inquiry based laboratories as an intervention across a five-week period. Achievement, attitude and motivation were documented in Pre and post assessments. Data collection strategies included selected response check-ups, surveys, and classroom observations. Twenty-eight (28) High School Physics students enrolled in the researcher's Physics class participated in this study. Collected data were displayed in bar graphs to detect patterns. It was found that inquiry learning in a laboratory setting has a similar effect on student achievement and motivation as the traditional approach, but can increase student attitude by promoting discussions and increasing student learning through errors. It is suggested that future research focus on the effects of errors on the learning process in a physics laboratory.

Table of Contents

Introduction

Significance

This action research study is significant because it directly impacts the curriculum and instruction in the researcher's high school physics class. The researcher received his initial certification in physics and general science from New York State in August 2011. He has been teaching physics at the high school level for four years, the first of which being part time, the last three years full time. The results of this study will directly impact the researcher's instruction. The researcher's own experience as a high school Physics teacher has informed the problem and directly impacted the research questions.

Problem

High school students in science laboratory classrooms often times struggle making connections between material learned in class and steps taken during a lab activity. During a traditional approach to teaching science labs, teachers use direct instruction to tell students what steps to take, what to calculate, how to show their data, and even sometimes what conclusions to draw. This traditional approach to teaching science labs causes a problem because students don't learn concepts, they just learn steps and following directions. Many science teachers are beginning to experiment with using an inquiry approach in their labs. An inquiry style approach allows the student to take the role of the scientist and the inquiry guides their way through an experiment. Inquiry based physics labs are different from the traditional lab mainly in one way. In traditional lab instruction, the teacher tells the student steps to take for the procedure during the lab and the student focuses on following the procedure. In an Inquiry lab, the students determine their own procedure and data analysis without direct instruction from the teacher.

Purpose

The purpose of this research study was to study the effects of guided inquiry on a Regents physics high school class. The researcher investigated how the student's attitude, motivation, and achievement were affected by a guided inquiry approach to lab activities.

Research Question

How does a guided-inquiry based laboratory impact motivation, attitude, and achievement in a high school Regents physics classroom?

Literature Review

What is Inquiry Learning?

Sincero (2006) and Zion and Mendelovici (2012) described inquiry-based learning as student-centered learning derived from student questioning, interest, curiosity, and background knowledge which allow the student to dive deeply into the material. During an inquiry activity, student's minds and hands are actively involved in the learning process facilitated by the teacher. In science, collaboration is often used during inquiry because it allows opportunities for students to question, create, and experience real-world experiments that resemble what scientists and engineers perform on a regular basis. This is how students develop a deep understanding of content knowledge. Sesen and Tarhan (2013) define a laboratory setting as an environment where students coordinate together in small groups. The following literature review explores the concept of inquiry learning within the field of physics, and in particular a laboratory (lab)-focus on physics.

Traditional and structured inquiry.

Traditional cook-book methods, also known as structured inquiry labs, provide students with a step-by-step procedure guiding them towards a preset outcome (Zion and Mendelovia, 2012). During traditional labs students are given a step-by-step procedure to complete the lab (Sesen and Tarhan, 2013). The procedure for traditional labs has students use hands-on skills and basic inquiry skills, but they do not gain much practice thinking independently because the lab predetermines the steps to take, questions to ask, and even results of the activity. Students also put most of their focus on the steps of the procedure and not a deep understanding of the topic (Sesen and Tarhan, 2013). This traditional style of lab can help a student gain experience with drawing a conclusion based on evidence, but high level inquiry skills are not developed (Zion and Mendelovia, 2012). Many science teachers have shifted from traditional labs to a guided inquiry style of learning.

Guided inquiry.

Zion and Mendelovia (2012) defined guided inquiry as a process where a question and focus is provided by the teacher and students collaborate together to determine a procedure that will guide them to a solution. It is based on an approach where students are allowed to evaluate their own procedure ability through the mistakes they make or their ability to develop an effective procedure to complete a lab experiment (Sever and Guven, 2015). An important part of guided inquiry is the results of the student procedure are not known beforehand and results are not anticipated by the teacher or students. In guided instruction, an active student is required to lead the process, make decisions on how to collect and interpret data, and come up with a conclusion based on what they saw (Zion and Mendelovia, 2012). An active student asks questions, hypothesizes, and uses deep thinking to attempt to solve a problem. Some teachers prefer guided inquiry because wasted time is avoided as students are given the guidelines of the task to complete and it keeps them on the path towards the goal without telling students what steps to take. This can lower student frustration levels because students don't have to deal with failure as much as with open inquiry. Many researchers have studied guided inquiry and its effects on student learning.

Sadeh and Zion (2012) conducted research to investigate what student's attitudes were towards inquiry learning, based on benefits, investment of time, and the task of documenting. In addition, they documented attitudes towards the amount of effort that was involved in each step of the inquiry process. They studied 295 high school biology students who attended 12 different high schools in Israel. All students took biology in 11th and 12th grade. One hundred sixty two (162) students participated in open inquiry and 133 in guided inquiry activities to see which students preferred. Students took a three section questionnaire that was used to determine their attitude towards inquiry activities. In the first section students responded to statements by marking one of five levels from 'strongly agree' to 'strongly disagree.' The second section provided students a list of possible responses and allowed students to choose more than one for each question. The final section was open-ended which allowed students to write their own response. The three sections increased the validity of the questionnaire and provided a better-rounded picture of student's opinions towards open and guided inquiry. Like Sesen and Tarhan (2013) and Banerjee (2010), data showed that students who participated in open-inquiry activities felt they took more away from the activity than students who completed the guided-inquiry activities (Sadeh and Zion 2012). Students who completed the guided-inquiry activities felt they documented more, which took up much of the time during the activity, and students who completed the open-guided activities spent more time preparing and completing the activity. The open-inquiry group also noted that they and their peers were the largest influence to their project as they cooperated together towards a common goal, showing the student centeredness of the activity (Sadeh and Zion 2012). Overall 263 of the 295 students in the study said that the inquiry project was beneficial to their learning, similar to findings of Sesen and Tarhan (2013), Banerjee (2010), Harrison (2014), and Bryant (2006).

Open inquiry.

Open inquiry is a learning process where the teacher develops the framework of the learning and students formulate the questions to ask (Sadeh and Zion, 2012). During this process students make many decisions from finding a question, what data to collect and how, and how to analyze their data. Open inquiry pushes students to use high-order critical thinking skills as it reflects research tactics that are used by scientists such as questioning, designing an experiment, critical thinking, and reflection (Zion and Mendelovia, 2012). The most important part of open inquiry activities is how it is set up by the teacher. Students need to be trained how to ask good questions and teachers to effectively facilitate open inquiry learning, otherwise the effectiveness of this style of learning is diminished. If done effectively, open inquiry can lead students to critically and scientifically think about their data in complex forms such as concept maps and graphs. It can also provide students with a greater ownership of the activity because of how involved they are with decision making (Zion and Mendelovia, 2012). Educators who prefer open inquiry do so because it allows students to better reflect scientific research by being active and collaborating in a group, and students are required to use higher level thinking skills, an area where a traditional approach failed. The guided inquiry approach used in this research study is rooted in constructivist theory.

Constructivism

The constructivist theory states that the student constructs knowledge in their own mind (Bodner, 1986). A student will try to make sense of incoming information by reflecting on what they already know and look for patterns. A learner will fill in the gaps with prior knowledge, whether it be correct or incorrect (Bodner, 1986). It was believed that knowledge could be transferred from teacher to student. However research shows that even with a good teacher, students won't learn through a flawed method (Bodner, 1986). A constructivist views teaching as the student knowing what is going on in their mind, but the environment around them is the unknown. The teacher can control what and how they teach a student, but the effect it has in the student's mind can be an unknown (Bodner, 1986). During education, a constructivist believes that an active student learns best. Constructivism can also help explain the reasoning for misconceptions in physics. If students use their prior knowledge incorrectly or for the wrong reason, it causes them to build a misconception, or inaccurate new knowledge (Bodner, 1986).

Linking closely to constructivism, inquiry learning also focuses on an active student (Zeynep and Alipasa, 2012). It requires a shift from a traditional lecture style classroom where the teacher stands at the front of the room. Both a constructivist approach and an inquiry approach call for the teacher to act as a facilitator to student learning (Bodner, 1986). To facilitate, a teacher organizes the environment to provide students with opportunities to create their own knowledge and be the center of the learning process. The correct answer isn't the focus, the process of problem solving is because it's where the student learns and builds knowledge (Zeynep and Alipasa, 2012). Laboratories provide a great environment for collaboration between students as their interests and prior knowledge guide them through an activity, but the lab and classroom needs to be set up to encourage this. The beginning of an activity should be set up with a problem that requires students to collaborate to reach a common goal (Zeynep and Alipasa, 2012). A constructivist laboratory encourages an active learner who builds concepts, while the teacher facilitates and motivates. There is an emphasis placed on the input of information in the student's mind, not the output from the teacher. An inquiry-based approach to teaching has students making hypotheses, designing ways to test their hypothesis, and then analyzing the story their data tells. A constructivist believes that knowledge is useful when it helps us reach our goal, for example if the analysis of lab data point towards a conclusion (Bodner, 1986). A constructivist and inquiry approach to education both recommend a teacher that facilitates an active student.

Dewey and Bruner

John Dewey (1910) and Jerome Bruner (1963) set the theoretical groundwork of inquiry-based learning style that is often practiced and researched today. John Dewey (1910a) suggested that the foundation of learning be built around reflective inquiry because it gives the learner options to figure out how to get around the obstacles of a given task. Dewey (1910b) further claimed that science learning suffered because it was presented as facts to be learned instead of material that needed to be questioned and reflected upon using an inquiry approach. He also suggested that students need to take an active part in science and be immersed in it, not stand passively on the sidelines. Students taking part in inquiry learning use their critical thinking skills to determine the nature of a problem before finding a possible solution. Inquiry also gives students a tool to determine the reason behind an outcome in science (Dewey, 1910a), which is more powerful than direct instruction. The author wrote that certain exercises in education can build different abilities, such as observation, critical thinking, or judgments (Dewey, 1910a). His constructivist approach is one of these types of exercises that can be used to hone a lesson to build high level thinking skills. He claimed that a thinking being can act on the future without knowing what the future will be. This directly relates to how students need to be trained to complete lab activities where they determine a procedure without knowing what will be shown by the results so they can discover the relationships for themselves.

Similarly, in the 1950s and 1960s, Jerome Bruner studied discovery learning, a method of inquiry-based learning where the learner discovers facts and relationships for themselves, which he suggested is the best way for a student to learn (Adler, 1963). Bruner believed that a student doesn't learn a concept the first time presented; they need several opportunities to experience the material in order to truly learn it (Bruner, 1963). Discovery learning supplies this opportunity because students are analyzing the material several ways. Bruner (1963) also discussed a child's early learning years and suggested that allowing children to focus on manipulating exercises could have positive outcomes during the first two years of school. This is because manipulating exercises allow the student to learn patterns and relationships for themselves. Further, Dewey (1910b) stated that direct teaching violates student's intellectual integrity because it tries to force knowledge upon the student. Dewey agreed with Bruner's thoughts that inquiry and discovery learning opens up a student's mind to want to learn. The following section reviews the current science standards used by many science teachers across the country.

Next Generation Science Standards

The Next Generation Science Standards (NGSS) were created and finished by the National Research Council (NRC) in 2013 by a committee of 18 scientists, educational researchers, and educational standards and policy experts (NGSS, 2013). Twenty-six states, including New York, gave leadership to create the NGSS. These states agreed to give serious consideration in adopting the NGSS (NGSS, 2013). Eight states that have adopted the NGSS include California, Kentucky, Vermont, Connecticut, Delaware, Nevada, Iowa, and Maryland, but not New York State. These standards will provide a criteria for all students in the United States to achieve before graduating high school and are linked with the New York Common Core State Standards (CCSS).

The NGSS criteria contains three dimensions necessary to create each standard, practices, crosscutting concepts, and disciplinary core ideas. Practices are the skills to be learned by the student and disciplinary core ideas are the specific learning objectives for the standard. Crosscutting concepts are concepts that apply to multiple subject areas such as cause and effect or detecting patterns. An important shift from the old standards to NCSS is connecting science education with experiences in the real world to reflect the importance of science and engineering in being 21^{st} century readiness (NGSS, 2013). Twenty first (21^{st}) Century readiness means that students are ready for the challenges in colleges and careers in the future.

The NGSS places a focus on deep and thorough understanding of content and how to synthesize it with material learned in other classes and other subjects (NGSS, 2013). The application portion is where the NGSS place an increased emphasis on engineering and technology to reflect a changing world. New challenges, such as providing clean energy or environmental changes, provide the rationale for the shift in emphasis as students will apply their knowledge to practical scenarios. It is thought that the NGSS will better prepare students for college and future careers through preparation of critical thinking and inquiry-based problem solving skills because they will be actively engaging in practices, hypothesizing, organizing data, and drawing conclusions, and not passively learning about topics (NGSS, 2013). These skills will be particularly important for current job opportunities, because there is a large reported number of job openings each month, more than three million, since 2011 in the areas of science, technology, engineering, and mathematics (NGSS, 2013). This literature review and thesis research focuses on physics laboratories. Therefore, the following section articulates NGSS related to physics.

Next Generation Science Standards in physics and STEM.

The NGSS create a new focus across the United States for students to reach a benchmark about all sciences. The new focus means all students are required to take a class that includes physics. According to NGSS, the main topics in the NGSS for physics are Forces and

Interactions, Energy, Waves and Electromagnetic Radiation, Structure and Properties of Matter (NGSS, 2013). The message of the NGSS and STEM (Science, Technology, Engineering, and Mathematics) educational programs in schools across the country are very similar: place a national priority on these fields because of their importance to future economics and job opportunities (NGSS, 2013; Gonzalez & Kuenzi, 2012). Each standard has a section titled Crosscutting Concepts where the NGSS focus on learning science material and concepts behind a topic and then connecting them to engineering and technology.

The STEM program was created to raise awareness for STEM education to keep the U.S. an economical and technological leader. It consists of 13 agencies, the Committee on STEM Education (CoSTEM), working together to create a strategy to impact education and is led by France Cordova, director of the National Science Foundation, and Jo Handelsman, Associate Director for Science, White House Office of Science and Technology Policy (Office of Science and Technology Policy, 2011). The STEM program mission is to inform the federal and state governments of this issue. STEM also provides funding for schools to develop their programs to educate students in the areas of science, technology, engineering, and math. The NGSS, STEM, and inquiry-based learning are all connected in shaping what the future of education will look like. All are connected in the belief that a student won't be able to understand science and engineering without the use of inquiry practices (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012). Inquiry is defined by the authors as hands on approach where students will be engaged in both knowledge and skill during practice. Inquiry is not passive learning; students are pushed to critically think, use precision, be objective, and evaluate each step that is taken (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012).

NGSS Science and Engineering practices are shown in Table 1. These practices are supported by the idea that science should be taught via inquiry because this is how practicing scientists have to present their findings, and through diagrams, orally, writing, tables, or graphs (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012). These are skills students should learn by the time they graduate from high school.

By the 12^{th} grade, students should have developed the ability to design an inquiry procedure to reach a solution. Students need practice in how to design a procedure and that's what labs in science class can provide, a place to practice inquiry. The knowledge of a specific topic is not the only thing learned, but also how to construct and perform a scientific experiment (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012). Students cannot fully understand science and engineering without having engaged in inquiry processes in both. Table 1 discusses how students can learn from supporting their claim because it requires them to argue based on evidence they have collected and analyzed, which is highly involved in inquiry.

Table 1

NGSS Science and engineering practices summarized

		Grades 9-12		
Practices	**Asking questions and defining problems**	**Modeling**	**Planning and carrying out investigations**	**Analyzing data**

Table 1 continued

Components	Evaluate a question	Evaluate merits and limitations of two different models	Plan an investigation or test to produce data	Analyze data in order to make valid and reliable claims
	Ask questions that challenge an argument	Design a test of a model	Plan an investigation or test that is safe and ethical	Apply concepts of statistics and probability to scientific questions
	Define a design problem	Develop a model based on evidence	Select appropriate tools	Consider limitations of data analysis
			Make directional hypotheses	Compare and contrast data sets
			Manipulate variables and collect data	Evaluate impact of new data on current explanation of a system
Practices	**Mathematical and computational thinking**	**Constructing explanations and designing solutions**	**Engaging in argument from evidence**	**Obtaining, evaluating, and communicating information**
Components	Create or revise computational model	Make a qualitative and/or quantitative claim regarding relationships between dependent and independent variables	Compare and evaluate competing arguments or design solutions	Critically read scientific literature
	Use mathematical representations to describe a solution	Construct and revise an explanation based on evidence	Evaluate claims, evidence, and/or reasoning	Compare, integrate and evaluate sources of information presented in different formats
	Apply algebra techniques to represent and solve a problem	Design, evaluate, and/or refine a solution to a complex real-world problem	Respectfully provide and/or receive critiques on scientific arguments	Gather, read, and evaluate information from multiple sources
	Apply ratios and unit conversions		Construct, use, and/or present an oral and written argument	Evaluate the validity and reliability of multiple claims
			Make and defend a claim	Communicate scientific and/or technical information or ideas

Note: Information for the NGSS practices from NGSS (NGSS Lead States, 2013).

Students learn from mistakes because it allows them to analyze why a relationship acts the way it does. Mistakes can get students to think deeply about the observed outcome (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012). Figure 1 shows how the inquiry process should be used to conduct investigations as students use their best skills available to support their procedure (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012).

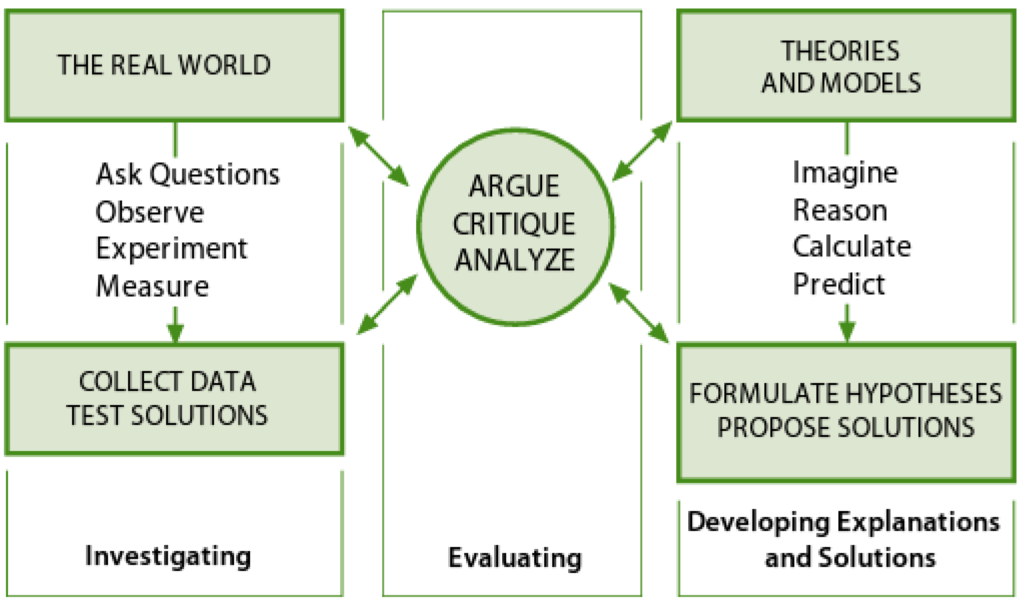

Figure 1. Three spheres of activity for scientists and engineers. (Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council, 2012).

The left sphere is related to the investigation where students plan and collect data. The right sphere illustrates how students develop a hypothesis based upon relevant knowledge. The middle sphere explains how students take all their data and experience in the investigation and draw an evidence-based conclusion. The NGSS emphasizes student readiness to apply the scientific method to make a claim that is based on evidence, supported by Table 1. The NGSS place an increased focus on physics across the U.S., much like the Regents standards do in New York.

New York State Regents Standards in Physics

According to current NYS graduation requirements, students are not obligated to take physics in high school in New York State. Students are required to take three total science classes with one of them being a Regents science class. Regents classes are a class with standards designed and set by New York State. Student then have the option to continue to take Regents level science courses or take non-Regents science courses. In any Regents science class students are required to complete a minimum of 1200 minutes of hands-on lab experience. Even though style of the laboratory activities is chosen by the teacher, an inquiry method is highly suggested (Board of Regents, 2002). The Regents standards (Board of Regents, 2002) promote the idea that inquiry should be used because it is a useful method to teach physics. It allows for students to be focused on real-world scenarios, be active, collect evidence, and collaborate towards an academic goal (Board of Regents, 2002). Inquiry is able to bring real-world questions that excite active learners to collaborate, as well as collect and use evidence to support a claim.

Table 2

New York State physics Regents standards summarized

Standard 1	Analysis, Inquiry, and Design
Standard 2	Information Systems
Standard 4	The Physical Setting
Standard 6	Interconnectedness: Common Themes
Standard 7	Interdisciplinary Problem Solving

Note: Information for the Regents standards from Board of Regents (Board of Regents, 2012).

A goal is for students to understand the concepts, mathematical relationships and process, not just the answer, which is what inquiry is useful for. As stated in the first Regents standard, students must be able to use analysis, design, and inquiry to determine appropriate questions, procedures, and solutions to scientific questions. As stated in key idea two of Regents standard one, students are required to test an explanation by a devised procedure and read their data to make an appropriate conclusion (Board of Regents, 2002). Engineering is also discussed in Regents standard one where learners are required to be able to design a process to solve a problem. Students are asked to develop visual representations to illustrate concepts and mathematical representations of a topic (Board of Regents, 2002). All of the mentioned skills are abstract and students will have to use the skills built through inquiry activities to create the representations of concrete data to communicate mathematically (Board of Regents, 2002). The remainder of this literature review synthesizes empirical studies from inquiry based laboratory settings.

Teacher Opinion of Inquiry Activities

Harrison (2014) studied how 16 teachers in Europe adapt to a change in pedagogy as teaching shifts from a deductive to an inquiry approach. These teachers were part of the Strategies for Assessment of Inquiry Learning in Science Project (SAILS) that created inquiry assessments and activities to prepare teachers to teach and assess science through inquiry methods. After becoming familiar with an inquiry approach, several teachers noted that they became more comfortable with assessing students on their skills (Harrison, 2014). They also reported that inquiry activities allowed them to collect more evidence of student performance by observation during the experiment because instead of leading the instruction, teachers could listen to conversations for misconceptions and perform formative assessment. A downside to observing students performing an inquiry activity is that a teacher may not be able to listen to each student or fully understand how much the students know about the topic (Harrison, 2014). Inquiry activities can also show teachers which students work well in a group and which do not (Harrison, 2014). It gives students an opportunity to share their ideas and teach each other. Teachers were also pleased to report that students were willing to learn from each other and their mistakes. However in order for inquiry activities to be successful in a classroom, students need to be introduced slowly to the new style of learning. If inquiry learning is introduced correctly, it can have a positive impact on student learning (Zion and Mendelovia, 2012).

Similarly, Seraphin, Philippoff, Parisky, Degnan, and Warren (2013) studied 47 middle and high school teacher’s opinions when introduced to inquiry activities based on energy consumption through professional development in Hawaii. A pre and post-survey was used to determine teacher’s opinion and comfort level towards inquiry activities. Teachers also participated in three modules focusing on energy auditing, photovoltaic solar energy, and wind energy. Teachers were taught how to teach students to evaluate and determine procedures to use during their inquiry investigations along with strategies to encourage students to interact and discuss with each other in a positive way. Professional development was broken into four sections, a two day workshop, an online peer forum, implementations, and follow-up meetings. Unlike Harrison (2014), the post-survey discovered that teachers were still uneasy about using inquiry to teach science (Seraphin et al., 2013), but this may be due to teachers being introduced to experts in the field of energy science. What teachers did like about inquiry was its ability to connect energy science to real life scenarios. Overall the professional development, like Harrison's (2014) findings, had a positive impact on teachers' ability to use inquiry activities to teach science (Seraphin et al., 2013).

Technology didn't make an impact in Laboratories

Many researchers experimented with technology in labs. Technology was added to traditional labs with the hope that it would increase student learning. Kuech, Zogg, Zeeman, and Johnson (2003, March) studied the effects of technology on misconceptions in an introductory biology course that is intended for students not majoring in biology in college. Participants were split into a control and experimental lab section and all students participate in labs based on photosynthesis. Researchers recorded and coded student's responses to questions and interviews after the laboratory. After they studied students for two semesters it was found that both lab sections had a large percentage of students, 44% for the "low tech" section and 35% for the "high tech" section, with misconceptions about where plants got the necessary carbon for growing (Kuech et al. (2003, March). Researchers concluded that the technology did not have a substantial effect on how students learned about the process of plant growth.

Similarly, Scott Wilson (2005) studied 70 students participating in a fluid power unit at the collegiate level. Participants were broken into four lab sections, two control and two experimental groups. All students received the same lecture on fluid power, but the control group completed two traditional lab assignments and the experimental group completed the same assignments using computer simulations. An evaluation was given to each student after the lab activities where they were given 15 minutes to complete three tasks about fluid dynamics and then scored from zero to three based on how many tasks they successfully completed (Wilson 2005). After the evaluation data were analyzed, researchers found that there was no significant difference between the scores of students from the control group and experimental group showing that computer simulations didn't have an impact on how students learned about fluid power (Wilson 2005). Their findings reflect Kuech et al.'s (2003, March) about the ineffectiveness of integrated technology in a laboratory.

Researchers, Lahoud and Krichen (2010), studied the effects of remote labs and computer simulations on student learning in an Information Technology (IT) and networking class. Fifty-five students from several universities and traditional colleges with online programs were studied, 33 male and 22 female, with a majority, 62%, interested in fields related to IT. Students were given a survey with 10 questions about their demographics and schooling, 13 questions about their attitude towards the networking labs, and 2 free response questions about their lab environment. Participants had a wide variety of demographics because they were from different colleges and universities and were familiar with online labs and simulation software. On the attitude portion of the survey, students could respond on a scale from one to five, very dissatisfied to very satisfied. Results showed that students tended to be more satisfied with traditional labs than online or simulations (Lahoud and Krichen, 2010) even though more students desired online or simulation labs than traditional. Researchers concluded that this could be because of the scheduling flexibility simulation and online labs provide.

Researchers Kuech et al. (2003, March), Lahoud and Krichen (2010), and Wilson (2005) all studied the effects of technology on a lab setting. They found that technology did not cause an increase in student learning when compared to a traditional learning style. Although one study (Lahoud and Krichen, 2010) did find that students may prefer technology integrated into labs, it is not an effective way to increase student achievement (Kuech et al., 2003, March, and Wilson, 2005).

Inquiry Methods made a positive impact in Laboratories

Zion and Mendelovia (2012) added two levels to inquiry learning, guided inquiry and open inquiry. During guided inquiry, students were given a question to study and they determined the steps necessary to answer the question. But in open inquiry, students were given the topic under investigation, and students discussed with each other and decided what questions to ask and determine a procedure to answer them. During any inquiry laboratory experiment students investigated a scientific question, determined how to collect evidence, evaluated their data, connected their data to their scientific knowledge, and formulated an argument based off their evidence (Banerjee, 2010). This lab style can cause students to think deeper about what steps they are performing and why they are using them.

Banerjee (2010), Bryant (2006), Kipnis and Hofstein (2008), and Sesen and Tarhan (2013), investigated implications of inquiry-based activities on student learning in science laboratories. These authors found that inquiry-based lessons had a positive effect on students learning in a small lab group of three to four students. Labs were set-up to be student centered which meant discussion between group members was highlighted and vital in reaching the goal of the activity. Bryant (2006), and Sesen and Tarhan, (2013) studied smaller samples, around 50-60 participants, for around three weeks each, while Kipnis and Hofstein, (2008) qualitatively examined their sample over eight years with a much larger sample size. Banerjee (2010) used a mix of qualitative and quantitative research methods with a team of 10 high school teachers. Even though each research group focused on different sample sizes for different length of time and depth, each group saw positive effects of inquiry-based lab activities on student learning (Bryant, 2006; Kipnet et al., 2008; Banerjee, 2010).

Motivation and attitude.

Sesen and Tarhan, (2013) observed 20 out of 100 lab activities finding that inquiry activities promoted students to see the usefulness of chemistry in the world around them. Students in this research study took a pre and post electrochemistry test (EAT) and an Attitudes Toward Chemistry Lesson and Laboratory Scales (ATCLS) test. Student's knowledge of electrochemistry was shown through the EAT, which was comprised of eight open-ended questions which were scored two, correct, one, partially correct, and zero, incorrect or no response given. The EAT also had 12 multiple choice questions which were scored one, correct, or zero, incorrect or no response given. The ATCLS showed what students' attitudes towards chemistry were like before and after instruction. Questions on this test fell into one of four categories, interest in chemistry lesson, understanding and learning chemistry, the importance of chemistry in real life, and chemistry and occupational choice. The students who were part of the experimental group participating in inquiry activities scored higher on the ATCLS than their peers in the control group who participated in traditional style activities (Sesen and Tarhan, 2013). This showed how inquiry-based activities increased students' attitudes towards chemistry and it also showed that they enjoyed the chemistry lesson more. Students in the experimental group placed a higher value on learning the foundational skills because they found them important for understanding chemistry. Researchers concluded that students enjoyed chemistry more because inquiry-based activities allowed students to learn chemistry concepts in a way that was meaningful to them and this led to the decrease in their negative attitudes (Sesen and Tarhan, 2013).

Unlike Sesen and Tarhan (2013), Banerjee (2010) conducted research in Georgia with a team of 10 high school teachers who guided students through 12 inquiry labs. Pre-tests and post-tests were used to determine how much students learned and their opinions about each lab setting, inquiry and traditional. Similar to Sesen and Tarhan (2013), the pre-test revealed to Banerjee (2010) that inquiry teaching had a positive effect on student's attitude towards a chemistry laboratory. Test results showed that 54% of students thought inquiry labs helped them improve self-confidence, 83% liked guided inquiry, while 40% favored traditional style labs (Banerjee, 2101). Similarly, teachers found students more likely to be motivated learners in the classroom when a more open, inquiry activity is done (Harrison, 2014). Sever and Guven (2015) studied 95 7^{th} grade students in an elementary school in Turkey who were chosen for their maturity level, as they were old enough to take responsibility over their own behaviors. Students with resistant behaviors such as not participating, showing little interest, or disrespecting the teacher were identified to be a focus of data analysis. To determine student attitude towards learning science and technology, researchers used observations, follow-up forms, video recordings, and student interviews to detect major themes. Similar to other findings (Sesen and Tarhan, 2013; Banerjee, 2010; and Harrison, 2014) Sever and Guven (2015) found that during interviews, students reported to enjoy inquiry activities the most and didn't report many negative comments about the activity. The video recordings showed that students with a tendency of resistant behaviors in the classroom had a positive influence from the inquiry activities as their resistant behaviors decreased in frequency (Sever and Guven, 2015). Also the ATCLS that Sesen and Tarhan (2013) used showed that students had a better attitude towards chemistry when completing inquiry labs. However, Banerjee (2010) discovered that many students felt that inquiry laboratories didn't prepare them for high stakes tests and college courses because inquiry activities are not performed in college. Contrary to student opinion, Bryant (2006) found that inquiry activities can increase student motivation and attitude towards class and therefore can have positive effects at the collegiate level.

Student on-task behavior.

Sesen and Tarhan (2013) compiled data from the ATCLS and found that it also showed inquiry-based activities had an impact on students' behavior in lab as students were more ready for lab work and completed their lab reports more effectively. Most likely students in the experimental group completed the labs easier because they placed a higher emphasis on the basics of chemistry allowing them to understand the steps they were taking in lab. Likewise, Sever and Guven (2015) looked at the effect of inquiry-based activities on behaviors of students in a 7^{th} grade science and technology course. Ninety-five students in Turkey participated in the research and were split up at random into a control group and experimental group. Students took a pre and post-test to determine growth in the activities and they also were interviewed and observed to determine behavior and attitude. After implementing the inquiry-based learning, teachers noted that it had a positive effect on student behavior in the classroom, but only when they were working on the inquiry activities (Sever and Guven, 2015). Both research groups, Sesen and Tarhan (2013) and Sever and Guven (2015), found that an inquiry-based learning style had positive impacts on student behavior in a lab setting allowing the students to complete the labs easier and more effectively.

Student achievement.

Kipnis and Hofstein (2008) and Sesen and Tarhan (2013) studied high school chemistry labs, in Israel and Turkey respectively, using observations of lab groups completing inquiry activities. They found that students who participated in the inquiry-based labs performed better on the EAT and the students performing the traditional labs had more misconceptions about the material (Kipnis and Hofstein, 2008, and Sesen and Tarhan, 2013). Sever and Guven (2015) similarly found that students who participated in inquiry activities learned more than their peers who completed a traditional lab activity. Kipnis and Hofstein (2008) used observations, interviews, and reflective essays to analyze students learning. They found that inquiry-based labs encouraged students to practice using their metacognitive skills in a natural way. A student's metacognition is described to fall into one of two categories, monitoring and self-regulation, or metacognitive knowledge about persons, strategies, or tasks (Kipnis and Hofstein, 2008). Students were found to ask each other to support their claims about the proper procedure which led them to a better understanding of their path to the solution of the lab. Both Kipnis and Hostein (2008) and Sesen and Tarhan (2013) saw that inquiry-based labs promoted the development of hands-on and social skills in a lab setting. Students questioned what they saw, not accepting it for the obvious but to try to understand it. The inquiry labs also prompted students to expose their knowledge of chemistry through the questions they asked each other. Similarly, Bryant (2006) researched college level physics inquiry labs and discovered that students tended to perform better on inquiry based exam questions than non-inquiry based exam questions regardless of how much they struggled to complete the inquiry lab. He learned that it was important for the lab section to be closely linked with the lecture section of the class to insure the best learning for students. Like Kipnis and Hofstein (2008), Bryant (2006) discovered that reflection was an important step for students in order to master the topic of the lab. Their reflection allowed them to think deeply about the procedure of the activity and the meaning behind each of the steps they took.

Johnson, Zhang, and Kahle (2012) also researched the effects of good science instruction on student performance on high stakes tests, the Ohio Graduation Test (OGT). Good science instruction was deemed to have a student-centered classroom where students were actively involved in the problem solving process. Data were collected from 2002 to 2007, focusing on 176 students at Star Middle School starting in sixth grade and followed to tenth grade. The study group was comprised of 73% Caucasian, 22% African American, 3% Latino, and 2% other. The 11 teachers involved in the study were observed four times using the Local Systemic Change (LCC) classroom observation protocol developed by Horizon Research (Johnson et al. 2012). The LSC contained questions and rating scales to grade the classroom, lesson, and teacher on demographics, lesson, materials, and instruction (Horizon Research, 2005). They were given a rating from one to five based on how well they used inquiry as a part of four subscales, design of lesson, implementation of lesson, science content of lesson, and classroom culture (Johnson et al. 2012). If a teacher's mean score from the four subscales was a three or above, they were deemed to be an effective teacher. Based on these ratings, student's data were broken up into groups based upon how many effective teachers they had from sixth through tenth grade. Teachers were afraid that spending more time on investigations and less on drill and practice would negatively impact test scores, especially because there is little information about the long-term effects of inquiry curriculum (Johnson et al. 2012). However based on the data, students who had effective teachers in sixth and seventh grade outperformed their peers in eighth grade (Johnson et al. 2012). Furthermore, Johnson et al. (2012) had similar findings to Bryant (2006), Kipnis and Hofstein (2008), Sesen and Tarhan (2013), and Sever and Guven (2015), discovering that those students who had effective teachers in middle school outperformed those who didn't on the OGT. All students who had at least one effective teacher passed the OGT on the first attempt. Data is contrary to what the teacher's believe about drill and practice, students performed better when given the opportunities to experience science in a hands-on, student centered classroom.

Demirbag and Gunel (2014) studied the effects of inquiry based learning on science achievement, writing, and argument skills. There were 119 students in the study, 67 males and 62 females, who were in their third year at the Central Anatolian University in Turkey. Students were in four equal sections, two of which were randomly selected to be the experimental group and the other two were the comparison group. The groups received the same type of instruction, but the experimental group was exposed to multi-modal instruction where students were asked to demonstrate their knowledge by creating a picture, diagram, or math expression (Demirbag and Gunel, 2014). Students prior science grades in chemistry and physics were collected to judge a baseline, and then students were given science achievement tests as a midterm and final exam. Each test included five open-ended conceptual questions on the topics studied and it was found that the alpha value for each test was above .5 and therefore they were deemed reliable (Demirbag and Gunel, 2014). Researchers analyzed students' test scores and found that the experimental group outperformed the comparison group in terms of their quality of arguments given and their activity reports. Results showed that an argument-based inquiry-learning environment was successful in teaching college students science.

Another related study conducted by Thoron and Myers (2011) researched the effects of inquiry-based learning on student's ability to learn agriscience. Participants attended the National Agriscience Teacher Ambassador Academy (NATAA) in two sections of the same class and teachers of the class were highly qualified prior to working at NATAA. There were 437 students included in the study across ten schools in the United States included in the NATAA (Thoron and Myers, 2011). Participants were mostly white, 81.6%, and males, 58%, 148 students were in ninth grade, 134 students in 10th grade, and 23 students in 11th grade, and the control and experimental groups had very similar student populations. Most participants, 72.5%, didn't qualify to receive free or reduced lunch (Thoron and Myers, 2011). Experimental groups received subject matter in an inquiry-based approach to study whether this approach helped students learn material better, through a pre and post-test for each unit of the study. Data from two teachers' students and 23 students were removed because of absences to help ensure validity to results leaving 305 student's data to study (Thoron and Myers, 2011). Lessons were recorded and scored using a rubric to determine the level of inquiry used in the experimental groups and it was found that teachers effectively used inquiry to teach the experimental groups and traditional methods to teach the comparison groups. Students scored an average of 36.04 out of 100 on the pre-test showing they had a large potential for growth in agriscience. Post-test data showed that participants of the inquiry-based instruction scored significantly higher than the comparison group averaging 73.74 out of 100, as compared with the comparison group who averaged 60.80 out of 100 (Thoron and Myers, 2011). Data show that even though both groups learned about agriscience, the inquiry-based approach was a more effective approach than the traditional approach. It is noted that teachers received a week of training on inquiry-based teaching methods and this allowed them to be well-prepared to teach lessons that were student centered, used a variety of teaching strategies, and promoted students to spend time-on-task during the learning process (Thoron and Myers, 2011).

Similar to Thoron and Myers (2011), Sever and Guven (2015) used a pre and post-test to determine student growth after they either participated in inquiry-based lessons or traditional lessons. Analysis of variance was used to determine patterns and relationships between variables of the data. It was found that all students increased their mean scores on the post-test, but students who participated in inquiry-based lessons showed a greater increase in score than their peers who received traditional lessons (Sever and Guven, 2015). The data showed that both methods, traditional and inquiry, successfully teach students, but an inquiry approach can help a student learn more than they would normally learn through a traditional approach.

As demonstrated by researchers (Thoron and Myers, 2011, Sever and Guven, 2015, Demirbag and Gunel, 2014, Bryant, 2006, Johnson et al., 2012, Sesen and Tarhan, 2013, Sever and Guven, 2015, and Kipnis and Hofstein, 2008) an inquiry approach to learning science is an effective method. When compared to a traditional style, inquiry can lead to an increase in student achievement. This is because students are active participants in the learning process which gets them to think deeply and critically about steps they are taking and how it relates to material learned in class.

Purpose and Research Question

The purpose of this research was to study the effects of guided-inquiry-based lab activities on student motivation, attitude, and achievement in a high school Regents physics class in New York State. The question that guided this study was:

How does a guided-inquiry based laboratory impact motivation, attitude, and achievement in a high school Regents physics classroom?

Methods

Step One: Find a Research Topic

The researcher is a physics teacher at a city high school in Western New York. Through his teaching experience, the researcher noticed that traditional style labs were goal-oriented and didn't promote good connections to material studied in class. The researcher found it difficult to make deep connections between the steps taken in lab, and knowledge from the classroom. He researched different lab methods and found interest in an inquiry style of laboratory because it allowed the student to act as a real scientist in a lab setting. Through teaching, he has experience using guided inquiry labs to teach topics in the lab portion of class, but didn't know if inquiry learning strategies were more or less effective than the traditional counterpart. He also noted than inquiry laboratory activities would help create a more student-centered classroom filled with collaboration, which aligns with STEM and 21st century learning (Office of Science and Technology Policy, 2011). Furthermore he was attracted towards inquiry approaches because he wanted to use inquiry strategies in his physics classroom. As shown in Table 1, the NGSS teachers to have their students perform tasks similar to a real scientist, which is aligned with inquiry learning.

Step Two: Conduct Literature Review

The researcher conducted a review of literature to investigate the topic of inquiry-based laboratory experiments. The researcher heard about inquiry learning while studying at Grove City College and was interested in what it was and how it worked in the classroom. He found that inquiry meant students guided their own learning in a lab setting and the teacher acted as a facilitator to the learning (Sincero (2006) and Zion and Mendelovia (2012). Literature about inquiry approach used in science classes/laboratories was collected using EBSCO and ERIC as databases for the search. He used the search terms "science AND inquiry AND laboratories" as well as "Technology AND science AND laboratories" to focus the search on the desired topic. Foundational theorists John Dewey and Jerome Bruner were reviewed and the researcher noticed that inquiry learning had roots with both of the theorist's ideas about education. It was found that research did not find a positive correlation between student learning and technology in the classroom, which was very interesting to the researcher because many school districts promote the use of technology in the classroom. He continued to read about inquiry in the classroom; several articles gathered were organized and synthesized to analyze patterns in results. The researcher noticed that many research groups found positive outcomes of inquiry labs. Main topics of student motivation, achievement, and attitude towards labs emerged as a result of organizing. After that, research results were read and categorized. The researcher wanted to know if the same positive outcomes would happen in his own classroom.

As part of this research, the author also spent time researching STEM concepts, the current Regents standards in physics, as well as the new NGSS. It was found that the NGSS aligned closely with STEM, advocating for students to learn and use 21st century thinking skills. Also the Regents standards (Board of Regents, 2002) in physics are aligned very closely with inquiry learning. Overall it was found that inquiry learning had the possibility of increasing the quality of education in the researcher's classroom. This review of literature gave a substantial amount of knowledge to guide the research study.

Step Three: Select Research Questions

The problem of lab experiments acting as a goal and not a connection to material studied in class was identified in the literature. The researcher observed that students would be focused on completing each step in a laboratory experiment and not focused on the objective of the assignment. The researcher wanted to investigate and know how to better make a connection between the two. The researcher read research studies on the topic of inquiry approaches to science when he noticed patterns emerging about the effects inquiry learning had on the classroom. The following questions arose: Do inquiry-based lab activities improve student learning of physics in a high school Regents class better than traditional (sometimes called cook-book) methods? Do inquiry-based lab activities improve student motivation completing lab activities more than traditional (cook-book) methods?

Step Four: Determine Research Participants

Research participants in this study were juniors and seniors who were predetermined by the school schedule for the 2015 school year. For example, the researcher arrived to school in August 2015 and was given a list of two Regents classes and two lab sections; the participant groups were intact groups as selected by the school administrator, and not selected by the researcher for any particular reason. This study was planned for a relatively small sample size of 28 students from a city school district. Student participants were a mix of male and female. The population of students in Regents physics in this study was 70% Caucasian, 27% Hispanic, and 3% Black. Baseline tests performed by the high school indicated that most, 70%, of participants are at or beyond grade level for mathematics, but only 37% are at or beyond grade level for reading.

School Demographics

The school is located in a city in Western New York State. The high school contains 603 students, has a full time equivalent of 53.61 teachers, and a student to teacher ratio of 11.25. The student population's ethnicity is comprised of 51% white, 40% Hispanic, 8% Black, and 1% other. Fifty percent (50%) of the population is eligible for free lunches and 10% for reduced-price lunches. Within the district there are 1,982 total students, 252 labeled as ELLs (English Language Learners) and 225 students have an IEP (Individualized Education Program).

Step Five: Determine Research Design

This action research study used a quasi-experimental research design across five weeks. An intervention (the experiment) was used across three weeks. The intervention consisted of four inquiry laboratory experiments that the participants completed when they were in lab. During the first two weeks of the research project, the researcher collected baseline data on the existing traditional lab approach. Baseline data included short achievement tests and teacher observations. The intervention took place during the final three weeks of the study and introduced a guided inquiry approach to conducting labs. Students were trained on how to complete guided inquiry activities, a process where a question and focus is provided by the teacher, then students collaborate together to determine a procedure that will guide them to a solution (Zion and Mendelovia, 2012), between the second and third week of the research study. Training consisted of a 10 minute lesson on what guided inquiry is, how to determine a procedure, and how to organize and take accurate data. Students also participated in an activity where they practiced writing procedures for simple tasks such as making a sandwich and washing laundry to practice writing a procedure. The class then used their written procedures to discuss what is necessary in a procedure for an experiment. Outcome variables included achievement, and motivation. Outcome variables were measured at the beginning of week one, three, and at the end of week five. Students were separated into two lab sections. Two weeks of traditional lab activities were administered as a control and three weeks of guided inquiry lab activities were administered as the research focus.

Step Six: Data Collection Strategies

Achievement Quiz

Each achievement test was designed to take around 10 minutes for students to complete. Tests contained multiple choice questions based on the topic of the laboratory activity to be studied in order to gain a quick, but accurate picture of student understanding of the material. Questions that applied to the topic(s) were used from past Regents exams from the years 2011-2014 (Board of Regents, 2002). Students took an achievement test during weeks 1, 3, and 5. See appendix A and B for traditional and inquiry pre-tests.

Observation with Tally

Observation with tally was used in this study to help the researcher record data while observing his students, while they complete both traditional style and inquiry style labs. The researcher focused on target behaviors such as number of times students had a deep discussion about the lab and how many questions they asked the teacher during inquiry practices. There were tallies for the number of occurrences of each behavior to organize and help identify any patterns that emerged and to provide anecdotal information to inform the outcome variables. The researcher hoped that observed data will show a pattern to how students behave in traditional versus inquiry lab settings.

The researcher had a high school student completing an independent study during the two lab sections who assisted with the research. The researcher trained the assistant how to observe and tally target behaviors by having a discussion about what each category meant, examples that would fit each category, and examples that would not fit each category. The researcher also completed the chart with the assistant the first two lab periods. When the researcher felt the assistant had a good understanding of the protocol, then the assistant took over the role of tallying target behaviors. This allowed the researcher to assist and teach the lab sections.

Table 3

Sample Observation Log

Week 5	Asking teacher questions	Deep discussion	Stuck	Error
19-Oct				
20-Oct				
21-Oct				
22-Oct				
23-Oct				

Self-Assessment survey about student attitude

Student self-assessments were created to gain a more well-rounded picture of how student attitudes were towards inquiry learning in a lab setting. Students were asked to rate themselves on a scale from one to five (strongly disagree to strongly agree, respectively) on a number of statements. Tapper's (2011) survey was based on student attitude in mathematics class, included “This lab interested me” “I learned better from working in a lab group” “I was sure of myself when completing this lab activity” and “I was eager to participate in the lab activity.”

Table 4

Student Self-Assessment – Traditional Approach

Choose from highly agree to highly disagree for each question. Your answers will be anonymous so do not put your name on the paper.

1. The traditional lab approach interested me.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

2. I enjoyed completing traditional lab activities

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

3. I learned better from working in a lab group.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

4. I felt comfortable participating and sharing my ideas with my lab group during traditional lab activities.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

Table 4 continued

5. I think I am good at physics.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

6. I was sure of myself when completing traditional lab activities.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

7. I was eager to participate in traditional lab activities.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

8. When completing traditional lab activities I enjoyed working in a lab group better than working alone.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

9. Knowing physics is useful in life.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

Table 5

Student Self-Assessment – Inquiry Approach

Choose from highly agree to highly disagree for each question. Your answers will be anonymous so do not put your name on the paper.

1. The inquiry lab approach interested me.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

2. I enjoyed completing inquiry lab activities

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

3. I learned better from working in a lab group.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

4. I think I am good at physics.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

5. I was sure of myself when completing inquiry lab activities.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

Table 5 continued

6. I was eager to participate in inquiry lab activities.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

7. When completing inquiry lab activities I enjoyed working in a lab group better than working alone.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

8. Knowing physics is useful in life.

Highly Agree	Agree	Neutral	Disagree	Highly Disagree
5	4	3	2	1

Step Seven: HSR Approval

The researcher submitted an HSR (Human Subjects Review) application to Dr. Mahoney in May, 2015. The researcher received a letter on June 15, 2015 stating that the research was approved and valid from September 21, 2015 through October 30, 2015. This letter can be found in Appendix C.

Step Eight: Intervention

During the final three weeks of the study students completed inquiry lab assignments. Labs completed were a gravity lab, acceleration lab, and a ground launched projectile lab. For the gravity lab students were given the following materials to use: electronic photogate timer, ball, stopwatch, meter stick, and measuring tape. Students were told that the objective of the lab was to use the given materials to write and carry out a procedure to determine an experimental value for the acceleration of gravity. During the acceleration lab students used near frictionless carts to study the acceleration down a ramp. The objective of this lab was to write and carry out a procedure to determine the acceleration of the cart traveling down the ramp. During the final lab, students wrote and carried out a procedure to determine the range of a dart launcher. For each lab, students had to get their procedures approved by me before they could collect any data.

Step Nine: Conduct Labs and Collect Data

Students were instructed on how to complete inquiry labs before the research study began to help increase the validity of the study. The researcher explained what guided inquiry labs were and how to complete them, and the researcher had students practice how to write a detailed procedure. Students were organized into five lab groups by the instructor to create heterogeneous mix. Students completed a-self assessment survey (attitude and motivation) and a short content area assessment during weeks 1, 2, and 5. Assessments were scored by how many questions out of 10 were correct and recorded by the researcher. Students completed seven lab activities during the course of the study. The researcher used a traditional lab approach during the first two weeks, and inquiry approach during the final three weeks. The researcher also used observation with tally to describe observed behaviors of each lab group. After each lab period the researcher filed the observation sheets and analyzed them at a later time. After week two and five, students were given a self-assessment to complete about their thoughts on each learning style.

Step Ten: Organize Data

After collecting data from pre-tests and post-tests, observations, and surveys, the researcher used Microsoft Excel to organize the data into one data base that contained five sections. These sections were titled "Raw Data Pre-Post Test," "Pre-Post Data Graphs," "Observation Data," "Observation Graphs," and "Self-assessment data." In the "Raw Data Pre-Post Test" section Pre-test and Post-test scores were separated by the two different learning styles, traditional and inquiry. Data in the section titled "Observation Data" were organized by category as well. Data were separated by learning style and daily tallies were marked accordingly to their observational category. The section "Self-assessment data" had data organized by traditional and inquiry approach as well. Student data were recorded into the database according to the statements on the surveys.

Step Eleven: Display Data

After organizing the data, the researcher used Microsoft Excel to graph trends for data set. For the pre and post test data the researcher used two bars in a bar graph to compare growth from pre-test to post-test for the two different approaches. For the observation data set, the researcher displayed another bar graph to plot the average number of instances of each target behavior per lab period. The data was separated by lab style. The last graph the researcher created used the student survey data set. The researcher graphed the average score for each statement onto a bar graph with data separated by lab style.

Step Twelve: Analyze Data

The researcher used the graphs he created to analyze the data. The graphs were created so that traditional and inquiry data were displayed next to one another so similarities and differences could be quickly detected and the researcher didn't have to sift through all the raw data.

Step Thirteen: Discuss Limitations

The researcher noted that there were limitations to this study. Some of these limitations include, a small sample size of only twenty-eight participants, a limited time of study of five weeks, and that students didn't have a lengthy experience with inquiry style labs previously in their educational experience. In order for inquiry activities to be successful in a classroom, students need to be introduced slowly to the new style of learning. If inquiry learning is introduced correctly, it can have a positive impact on student learning, if introduced incorrectly it can have negative impacts (Zion and Mendelovia, 2012). The small sample size limits the study from making broad generalizations about how students learn physics, but it did allow the researcher to study how inquiry learning works in his classroom. The time of the study was short, but four traditional labs and five inquiry labs were completed. This data set allowed the researcher to accurately study the effects inquiry laboratory learning had on students in his classroom, however it is likely that additional weeks may reveal additional trends. Lastly, because inquiry learning was a new experience for the participants, this may have limited the results. Since this is an action research study, these types of limitations are typical and did not impede the researcher from making classroom-level decisions after the results and conclusions were completed.

Results

Data were collected through, observations, a quiz, and student surveys as pre and post tests, then put into Microsoft Excel to be analyzed.

Pre and Post-Tests

Before and after the experiment, data were collected from a quiz containing ten multiple choice questions. Students were given ten minutes to complete the quiz before it was collected and scored. The researcher calculated that the average score out of ten for the traditional pre-test was a 2.3, with the median score being 2. The traditional post-test results yielded an average score of 5.2, with a median score of 5. The traditional section showed an average improvement of 2.9 from the pre-test to the post-test. The inquiry pre-test results showed an average score of 2.1 and a median of 2. The average for the inquiry post-test was a 4.3 and a median of 4. The inquiry section had an average gain of 2.2 from pre-test to post-test.

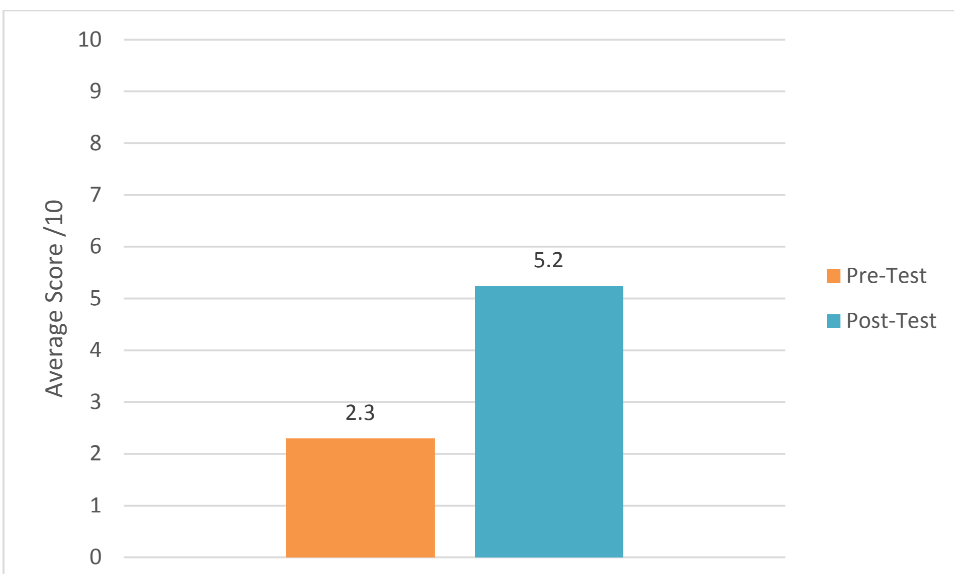

Figure 3: Traditional (comparison group-not Guided Inquiry) Pre and Post-Test Averages

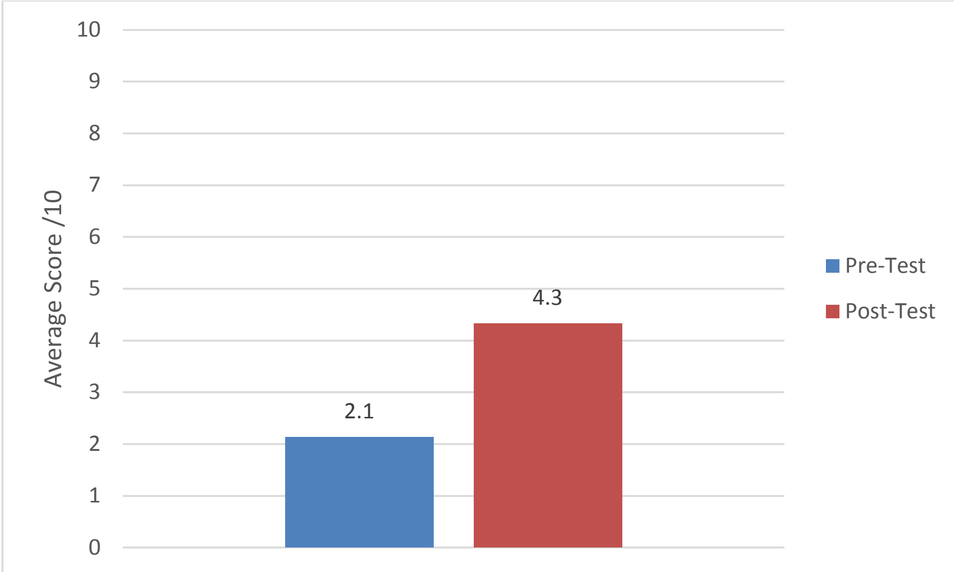

Figure 4: Inquiry Pre and Post-Test Averages

Observations

Tally sheets were created to help the researcher observe students as they completed both traditional style and inquiry style labs. The researcher focused on target behaviors of discussing and questioning. There were tallies for each lab class to help identify any patterns that emerge and to provide anecdotal information to inform the outcome variables. The researcher hoped that observed data would show a pattern about how students behave in traditional versus inquiry lab settings.

The researcher had a student completing an independent study during the two lab sections who assisted with the research. The researcher trained the assistant how to observe and tally target behaviors by having a discussion about what each category meant, examples that would fit each category, and examples that would not fit each category. The researcher also completed the chart with the assistant the first two lab periods. After which the researcher felt the assistant had a good understanding of the protocol and the assistant took over the role of tallying target behaviors. This allowed the researcher to assist and teach the lab sections. The tallies for traditional data can be found in Table 5 and the inquiry data in Table 6. Data are missing for September 12th because there was not school that day September 13th due to a lockdown drill, and September 14th due to students taking a PSAT exam.

Table 6

Observation tallies: Traditional Approach

Lab A/C	Ask Q	Discussion	Stuck	Error
14-Sep	4	0	1	1
16-Sep	3	1	1	2
18-Sep	7	1	1	0
22-Sep	2	1	4	0
24-Sep	3	0	2	0
Lab B/D	Ask Q	Discussion	Stuck	Error
15-Sep	1	0	1	0
17-Sep	4	0	1	0
21-Sep	8	1	2	3
25-Sep	1	0	0	0

Table 7

Observation tallies: Inquiry Approach

Lab A/C	Ask Q	Discussion	Stuck	Error
9/30/2015	1	1	1	1
10/2/2015	0	1	1	1
10/6/2015	1	0	2	3
10/8/2015	3	4	2	1
10/12/2015				
10/14/2015				
10/16/2015	2	1	0	0
10/20/2015	4	0	4	3

Table 7 continued

Lab B/D	Ask Q	Discussion	Stuck	Error
10/1/2015	3	2	1	1
10/5/2015	1	0	0	5
10/7/2015	3	0	3	4
10/9/2015	1	2	1	4
10/13/2015				
10/15/2015	4	2	3	3
10/19/2015	1	0	2	2

The observation data contained average tallies for number of occurrences of target student behaviors per lab period. These target behaviors were students asking the teacher questions about the lab, lab groups in deep discussion with one another, lab groups stuck, and errors made during the lab. During the traditional lab approach students asked on average 3.7 questions a lab period, had 0.4 deep discussions, got stuck 1.4 times, and made 0.7 errors. The medians of the target behaviors were 3 for questions, 0 for discussions and errors, and 1 for number of times stuck. During inquiry labs students asked on average 2 questions, had 1.1 deep discussions, got stuck 1.7 times, and made 2.3 errors. The medians of the target behaviors were 1.5 for questions, 1 for deep discussions, 1.5 for number of times stuck, and 2.5 for number of errors made. Figure 5 shows this.

Self-Assessment

The self-assessment was based on a five-point scale from one being “Highly Disagree” to five being “Highly Agree.” Average ratings for each statement were calculated and are as follows. Self-assessments for the traditional approach showed an average of 3.5 for lab interest, 3.5 for lab enjoyment, 3.7 on learning from working with a group, 4.0 on comfort of

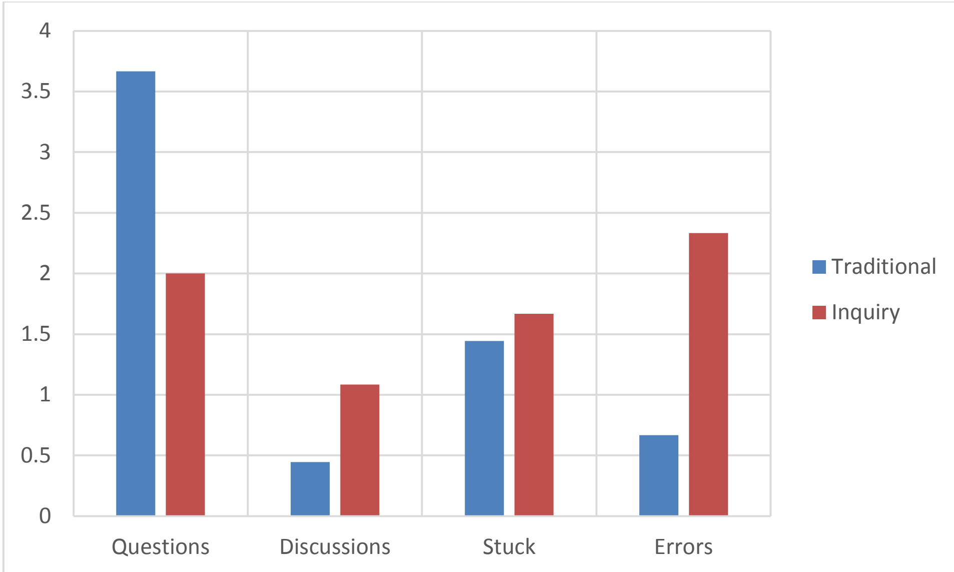

Figure 5: Average occurrences of target behaviors per lab period.

participation, 3.0 on confidence with physics skills, 3.6 on confidence during the lab, 3.3 for eagerness to participate, 4.1 for enjoyment working with a group, and 4.1 for the usefulness of physics in life. Students rated the inquiry approach as 3.6 for lab interest, 3.6 for lab enjoyment, 4.0 on learning from working with a group, 4.3 on comfort of participation, 3.0 on confidence with physics skills, 3.1 on confidence during the lab, 3.6 for eagerness to participate, 4.4 for enjoyment working with a group, and 4.1 for the usefulness of physics in life. The average change from the traditional to inquiry surveys was 0.1 shifting towards the “Highly Agree” statement.

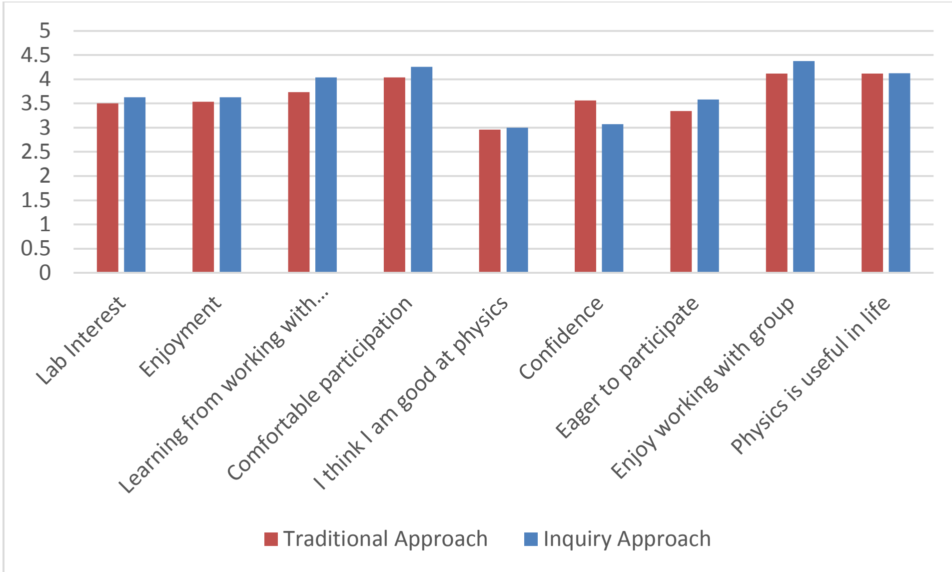

Figure 6: Average ratings from student surveys

Discussion

How does Guided Inquiry Based Laboratory Impact Motivation, Attitude, and Achievement in a High School Regents Physics Classroom?

The purpose of this study was to examine the effectiveness of inquiry style labs on attitude, achievement and motivation in a high school physics class in Western New York. It can be concluded that the traditional and inquiry lab styles are both useful tools for teaching physics in Western New York. Both styles lead to an increase from the pre-test to post-test assessments, students' opinions were similar on the student surveys, and tallies indicated that students conducted the two styles of labs similarly except for the amount of errors that were made and questions that were asked. During inquiry labs, students tended to ask less questions and make more errors.

Motivation

Student motivation completing traditional and inquiry laboratory experiments are shown through question seven of the student surveys. The average rating for the traditional approach was 3.3 and the inquiry approach was 3.6. These ratings indicate that students had close to neutral feelings about their eagerness to participate in the lab activity. The data also show that there was not a large difference in motivation between the traditional approach and inquiry approach.

Attitude

Student's attitude towards physics can be shown through the survey questions 1, 6, and 9. Students rated their interest in labs during question 1. Traditional results yielded a score of 3.5

and the inquiry shows 3.6. This demonstrated that students were interested in both lab styles the same. Question 6 studied student's confidence when completing labs. During the traditional approach students were more confident, scoring an average of 3.6, than the inquiry approach, scoring a 3.1. The researcher believes this result is because the traditional approach tells students what steps to take and the inquiry approach has students determine their lab procedures. This result also could be influenced by the fact that the participants had completed many traditional lab activities before the study, but had little experience completing inquiry style lab activities. Lastly question 9 studied student's views on how useful physics is in life. Traditional and inquiry results yielded an average of 4.1 showing that the two lab styles did not affect student's views on the usefulness of physics differently.

Achievement

Students answered on average 2.9 more questions correctly on the traditional post assessment and 2.2 more on the inquiry post assessment. These results indicate students learned better from the traditional approach than the inquiry, but the researcher concluded that there are too many variables to make an accurate conclusion and reflected on some of these reasons. Some other variables that may be causing these results include the material studied during the inquiry approach was more difficult than that of the traditional approach. The material during the traditional approach dealt with one dimensional kinematics, a unit that students tend to understand well. During the inquiry approach the class had moved onto two dimensional kinematics which tends to be a challenge for the average student. The material studied during the inquiry approach also builds upon the knowledge learned during the two weeks of traditional method, so any misconceptions or missing knowledge would be compounded in later sections. Another variable might be even though students were trained how to complete an inquiry lab, this research study was the first time students completed inquiry labs for a substantial amount of time. Before the study students had commented that they had practiced writing instructions and some had completed an inquiry lab, but none of the participants had completed more than one lab of this style. This variable was seen in the confidence level of students when completing inquiry lab activities, but there could have been more ill effects students had from participating in a new style of learning.

Inquiry Based Instruction Led to More Discussion

Although observation data showed only an increase of 0.6 deep discussions had during inquiry labs when compared with traditional labs, the errors students made during the labs promoted them to figure out the correct answer on their own. Correcting these errors led students to be an active learner which tends to allow students to learn better (Zion and Mendelovia, 2012). The researcher and research assistant found it difficult to observe students having deep discussions in their lab groups. They found it difficult to tell the difference between a discussion between two students and one student explaining what to do to another student. Having the researcher teach the lab class also made it difficult to observe discussions as the researcher was helping other lab groups, answering questions, or setting up equipment. Because of these difficulties the researcher predicts that there exists error in the tally data for deep discussions and no conclusion can be made about the effects of inquiry learning on student discussion during a physics laboratory activity.

Inquiry Based Instruction Led to Student Growth through Errors

During inquiry labs students on average made 1.7 more errors than when completing traditional labs. These errors led the students to go back, discuss, and rethink the steps they took or calculations they made to find the correct conceptual thinking. Pushing the student to go back and figure out the cause of their error leads the student to be an active learner which promotes a better learning environment (Zion and Mendelovia, 2012). Students were often guided by the teacher to look back through notes and example problems to find models that mirrored the lab activity. Looking back and figuring out the answer is also supported by the National Research Council (2012). During traditional lab activities students were told what steps to take and therefore, their focus in the traditional setting was primarily on setting up the equipment as the lab stated. Traditional learning does not create an active learner which doesn't allow students to learn as well (Zion and Mendelovia, 2012). Inquiry learning remedies this problem by having the student actively think about the steps they are taking toward a solution.

Recommendations

After analyzing the data, the researcher has questions about the trend of students making more errors during inquiry labs. The researcher is also interested in the effect inquiry learning had on student discussion, since the researcher found it very difficult to actively observe discussions when teaching the lab class. Further research should be done to study the effects of how making errors influences the learning outcomes of students when completing high school physics lab activities and the effects of inquiry learning on student discussions. Further research studies should also focus on a larger group of students, more than 200, to increase the validity of the study. The researcher suggests that future research have a control group completing traditional lab activities and a test group completing inquiry lab activities so that their scores and data could be analyzed side by side. This would increase validity because there wouldn't be a difference in the material that is studied during each lab approach. The researcher further suggests that future research study traditional and inquiry labs over a longer period of time, 8 weeks or more. To study the effects of inquiry learning on student discussions, the researcher suggests that further research be completed by someone who is not teaching the lab class so the new researcher could focus all their attention on student discussion. These changes to the research approach may yield more meaningful results.

References

Adler, M. (1963). *Some implications of the theories of Jean Piaget and J.S. Bruner for education*. Toronto: Research Dept., Board of Education for the city of Toronto.

Banerjee, A. (2010). Teaching science using guided inquiry as the central theme: A professional development model for high school science teachers. *Science Educator*, *19*(2), 1-9.

Board of Regents. (2002). *Physical setting/Physics core curriculum*. NY.

Bodner, G. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education, 63*, 873-878.

Bruner, J. (1963). *The process of education*. New York, NY: Harvard University Press.

Bryant, R. (2006). Assessment results following inquiry and traditional physics laboratory activities. *Research and Teaching, 35*(7), 56-61.

Committee on Conceptual Framework for the New K-12 Science Education Standards National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.

Demirbag, M., & Gunel, M. (2014). Integrating argument based science inquiry with modal representations: Impact on science achievement, argumentation, and writing skills. *Educational Sciences: Theory & Practice,14*(1), 386-391.

Dewey, J. (1910a). *How we think*. Boston, MA: D.C. Heath & CO.

Dewey, J. (1910b). Science as a subject-matter and as a method. *Science, 31*, 121-127.

Gonzalez, H., & Kuenzi, J. (2012). Science, technology, engineering, and mathematics (STEM) education: A primer. *CRS Report for Congress*.

Harrison, C. (2014). Assessment of inquiry skills in the SAILS project. *Science Education International*, *25*(1), 112-122.

Horizon Research (2005). 2005-06 Local Systemic Change Classroom Observation Protocol. Retrieved March, 2015, from http://www.horizon-research.com/horizonresearchwp/wp-content/uploads/2013/04/cop.pdf

Johnson, C. C., Zhang, D., & Kahle, J. B. (2012). Effective science instruction: Impact on high-stakes assessment performance. *Research in Middle Level Education*, *35*(9), 1-14.

Kuech, R., Zogg, G., Zeeman, S., & Johnson, M. (2003, March). *Technology rich biology labs: Effects of misconceptions*. Paper presented at the annual meeting of the national association for research in science teaching National association for research in science teaching., Philadelphia, PA.

Kipnis, M., & Hofstein, A. (2008). The inquiry laboratory as a source for development of metacognitive skills. *International Journal of Science and Mathematics Education, 6*(3), 601-327.

Lahoud, H. A., & Krichen, J. P. (2010). Networking labs in the online environment: Indicators for success. *Journal of Technology Studies*, *36*(2), 31.

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Office of Science and Technology Policy. (n.d.). Retrieved May 10, 2015, from https://www.whitehouse.gov/administration/eop/ostp/nstc/committees/costem

Sadeh, I., & Zion, M. (2012). What type of inquiry project do high school biology students prefer: Open or guided? *Research in Science Education, 42*(5), 831-848.

Seraphin, K., Philippoff, J., Parisky, A., Degnan, K., & Warren, D. (2013). Teaching energy science as inquiry: Reflections on professional development as a tool to build inquiry teaching skills for Middle and High school teachers. *Journal of Science Education and Technology, 22*(3), 235-251.

Sesen B. A., & Tarhan, L. (2013). Inquiry-based laboratory activities in electrochemistry: High school students' achievements and attitudes. *Research in Science Education, 43*(1), 413-435.

Sever, D., & Guven, M. (2015). Effect of inquiry-based learning approach on student resistance in a science and technology course. *Educational Science: Theory and Practice, 14*(4), 1601-1605.

Sincero, P. (2006, January 1). What is inquiry-based learning? Retrieved February 22, 2015, from http://www.inquirylearn.com/Inquirydef.htm

Thoron, A., & Myers, B. (2011). Effects of inquiry-based agriscience instruction on student achievement. Journal of Agricultural Education, 175-187. doi:10.5032/jae.2011.04175

Wilson, S. (2005). Computer assisted fluid power instruction: A comparison of hands=on and computer-simulated laboratory experiences for post-secondary students. *Journal of Technology Studies*, *31*(1), 57-61.

Zeynep, T., & Alipasa, A. (2012). Virtual chemistry laboratory: Effect on constructivist learning environment. *Turkish Online Journal of Distance Education*, *13*(1), 183-199.

Zion, M., & Mendelovici, R. (2012). Moving from structured to open inquiry: Challenges and limits. *Science Education International, 23*(4), 383-399.

Appendix A

Name:______________________________________

Student Pre-test : Traditional

Circle the best answer for each question. You will have 10 minutes to complete the assessment, after which your paper will be collected and stored securely.

1. What is the time required for an object starting from rest to travel 50. Meters if it is moving at a rate of 30m/s?
    a. 0.60s
    b. 1500s
    c. 20.0s
    d. 1.67s

2. The diameter of an automobile tire is closest to
    a. 10^{-2}m
    b. 10^{0}m
    c. 10^{1}m
    d. 10^{2}m

3. A car is moving with a constant speed of 20. Meters per second. What total distance does the car travel in 2.0 minutes?
    a. 10m
    b. 1200m
    c. 40m
    d. 2400m

4. A car is initially traveling at 15 meters per second north, accelerates to 25 meters per second north in 4.0 seconds. The magnitude of the average acceleration is
    a. 2.5m/s^2
    b. 10m/s^2
    c. 6.3m/s^2
    d. 20m/s^2

5. What is the final speed of an object that starts from rest and acceleration uniformly at 4.0 meters per second over a distance of 8.0 meters?
    a. 8.0m/s
    b. 32m/s
    c. 16m/s
    d. 64m/s
6. As a projectile travels towards it’s peak what happens to the magnitude of the vertical acceleration?
    a. acceleration increases
    b. acceleration decreases
    c. acceleration remains the same
    d. acceleration decreases, then increases

7. The straight line length measurement between the starting and ending position of an object is known as its
    a. Distance
    b. Displacement
    c. Speed
    d. Acceleration

8. A car is traveling to the north and is accelerated to the south. The car will initially
    a. Speed up in the northward direction
    b. Speed up in the southward direction
    c. Remain at a constant speed
    d. Slow down

9. In a drill during basketball practice, a player runs the length of the 30. Meter court and back. The player does this three times in 60. Seconds. The magnitude of the player's total displacement after running the drill is
    a. 0m
    b. 30m
    c. 60m
    d. 180m

10. Which term identifies a vector quantity?
    a. Speed
    b. Time
    c. Displacement
    d. Volume

Appendix B

Pre-test for Inquiry Approach

Name:______________________________________

Student Pre-test : Inquiry

Circle the best answer for each question. You will have 10 minutes to complete the assessment, after which your paper will be collected and stored securely.

1. What is the time required for an object starting from rest to fall freely 500. Meters near Earth's surface?
   a. 51.0s
   b. 10.1s
   c. 25.5s
   d. 7.14s

2. The components of a 15-meter-per-second velocity at an angle of 60.^{o} above the horizontal are
   a. 7.5 m/s vertical and 13 m/s horizontal
   b. 13 m/s vertical and 7.5 m/s horizontal
   c. 6.0 m/s vertical and 9.0 m/s horizontal
   d. 9.0 m/s vertical and 6.0 m/s horizontal

3. A ball is thrown with an initial speed of 10. Meters per second. At what angle above the horizontal should the ball be thrown to reach the greatest height?
   a. 0^o
   b. 45^o
   c. 30^o
   d. 90^o

4. A projectile is launched at an angle above the ground. The horizontal component of the projectile's velocity, v_x, is initially 40. Meters per second. The vertical component o the projectile's velocity, v_y, is initially 30. Meters per second. What are the components of the projectile's velocity after 2.0 seconds of flight? (neglect friction)
   a. V_x=40. m/s and v_y=10.m/s
   b. V_x=40. m/s and v_y=30.m/s
   c. V_x=20. m/s and v_y=10.m/s
   d. V_x=20. m/s and v_y=30.m/s

5. A baseball is thrown at an angle of 40.0^o above the horizontal. The horizontal component of the baseball's initial velocity is 12.0 meters per second. What is the magnitude of the ball's initially velocity?
   a. 7.71 m/s
   b. 15.7 m/s
   c. 9.20 m/s
   d. 18.7m/s

6. A rock is dropped from a bridge. What happens to the magnitude of the acceleration and the speed of the rock as it falls? (neglect friction)
    a. Both acceleration and speed increase
    b. Both acceleration and speed remain the same
    c. Acceleration increases and speed decreases
    d. Acceleration remains the same and speed increases

7. A soccer ball is kicked on a level field has an initial vertical velocity component of 15.0 meters per second. Assuming the ball lands at the same height from which is was kicked, what is the total time the ball is in the air? (neglect friction)
    a. 0.654s
    b. 3.06s
    c. 1.53s
    d. 6.12s

8. A student standing on the roof of a 50.0-meter-high building kicks a stone at a horizontal speed of 4.00 meters per second. How much time is required for the stone to reach the level ground below? (neglect friction)
    a. 3.19s
    b. 10.2s
    c. 5.10s
    d. 12.5s

9. Two 20-newton forces act concurrently on an object. What angle between these forces will produce a resultant force with the greatest magnitude?
    a. 0^o
    b. 90^o
    c. 45^o
    d. 180^o

10. Which term identifies a scalar quantity?
    a. Displacement
    b. Velocity
    c. Momentum
    d. Time

Appendix C

FREDONIA
STATE UNIVERSITY OF NEW YORK

15 June 2015

David Bittinger
c/o Kate Mahoney, Ph.D.
Language, Learning and Leadership
College of Education
The State University of New York at Fredonia

Re: David Bittinger— The Impact of an Inquiry Based Approach on Attitude, Motivation and Achievement in a High School Physics Class

Your research project using human subjects has been determined Category 1, Exempt, under the United States Department of Health and Human Services Code of Federal Regulations Title 45 Public Welfare, Part 46 Protection of Human Subjects, 46.101, Subpart A (b) (1) and/or (2). This document is your approval and your study titled "The Impact of an Inquiry Based Approach on Attitude, Motivation and Achievement in a High School Physics Class" may proceed as described. **Your approval is valid from September 21, 2015 through October 30, 2015.**

Thank you for keeping the high standards relating to research and the protection of human subjects under the auspices of the State University of New York at Fredonia.

Sincerely,

Judith M. Horowitz, Ph.D.
Associate Provost, Graduate Studies, Sponsored Programs
and Faculty Development
Human Subjects Administrator