

INQUIRY BASED LEARNING IN THE CHEMISTRY CLASSROOM

by

Bryan David Idleman

A professional paper submitted in partial fulfillment
of the requirements for the degree of

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana
July 2016

©COPYRIGHT

By

Bryan David Idleman

2016

All Rights Reserved

ACKNOWLEDGEMENTS

Thank you to Dr. Eric Brunsell for his time, patience, and motivation which helped to make this project successful. Also, I would like to thank you for being my mentor and guide throughout my MSSE program. Thank you to Dr. Elinor Pulcini for taking the time to serve on my committee and for editing and suggestions. A special thank you to John Graves for additional insight into the inquiry process. Thank you to Diana Patterson and Peggy Taylor for your support throughout the program and in ensuring that I didn't miss any steps along the way.

I would like to thank my principal, Roseyn Hood, for her support and suggestions as well as my peers including Patsy Jones for introducing me to the program; and, to Cauley Clark who was instrumental in lesson plan development. A special thank you to my family who supported my decision to return to school, helped proofread papers, developed games and offered suggestions over the past two years.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND	1
2. CONCEPTUAL FRAMEWORK.....	4
3. METHODOLOGY	9
4. DATA AND ANALYSIS	15
5. INTERPRETATION AND CONCLUSION	21
6. VALUE.....	23
REFERENCES CITED.....	25
APPENDICES	28
APPENDIX A.....	29
APPENDIX B	31
APPENDIX C	33
APPENDIX D.....	35
APPENDIX E	37

LIST OF TABLES

1. Student Numbers.....	11
2. Research Questions and Measurement Tools	15
3. Student Pre and Post Test Scores.....	17
4. Pretest and Posttest Normalized Gains	17
5. Midterm and Final Exam Averages	18
6. Student Survey Results	19

LIST OF FIGURES

1. Student Demographics:.....	11
2. Percent Gain:.....	18
3. Results Overview	21

ABSTRACT

Delivery of instruction can impact student learning in many ways. The purpose of this study was to determine the effectiveness of inquiry based instruction on student achievement and student attitude in high school Chemistry. Tests, surveys and interviews were used to compare data from one school year to the next. Quantitative data was gathered through a series of tests. These tests were used to determine gains in content knowledge and ability to solve problems. Surveys and interviews were used to measure qualitative data regarding the attitudes about learning chemistry. The control group was taught by traditional instruction through the use of lecture, note-taking, and textbook guided assignments. The experimental group was taught by the use of inquiry based lessons containing daily group activities, lab development, white-boarding and self-discovery tactics. The data in this study indicated that utilizing inquiry based instruction in the high school Chemistry classroom is an effective method for increasing content knowledge and positive attitudes about Chemistry.

INTRODUCTION AND BACKGROUND

Teaching and Classroom Environment

As a high school science teacher, I have noticed a disconnect with many students in the day to day learning of curriculum. Chemistry combines conceptual theory and mathematical computation which requires that students understand both the rationale and processes to determine outcomes. Many students understand concepts but struggle with the reasoning behind the mathematical processes in problem solving. Students often seem unengaged and go through the motions of steps taught without thinking about what these steps mean. As a teacher, I believe that motivated students are better learners and that gaining an understanding of the connection between the theory and mathematical processes will enhance their overall performance.

The purpose of this study was to determine the impact of inquiry based learning on student motivation and understanding of chemistry. Students in my Chemistry classes traditionally struggled with problem solving and comprehension. In order to better facilitate learning, I modified my teaching structure from a lecture based approach to an inquiry based learning model during two units in the second semester. My objective was for student perception pertaining to Chemistry to shift in a more positive direction. Positive perception, in turn, would lead to improved performance and a better understanding of conceptual material.

“Students’ perceptions are essential to understand student learning and the latter is improved by student-activating instruction, then the student-activating environment will

produce a differentiating effect on students' perceptions compared to lecture based settings," (Struyven, 2005).

My school is located in Gilbert, Arizona which is a city connected to the southeast corner of the Phoenix metro area. Twelve years ago, the area was primarily agricultural with many of the students living on farms or ranches. Today, with rapid growth, the area is mainly middle class families living in suburban homes. The area is economically diverse with low income housing located in the Arizona State Polytechnic Campus (formerly Williams Field Air Force base) and larger homes scattered throughout. Demographics of the school show that we are sixty-three percent Caucasian, twenty-one percent Latino, seven percent African American, five percent Asian, two percent Native American and two percent other race. Our school population is roughly one thousand seven hundred students. Twenty-five percent of our students qualify for free or reduced lunch (HUSD.org, 2015). Our high school incorporates the inclusion model which mainstreams special education students into the classrooms. Our district is rated as the top large school district in the state based on standardized test scores from last year (AZDOE.gov, 2014).

I averaged just under thirty-nine students for my four chemistry classes in the spring of 2016 ranging from thirty-four students to forty-four students. Students numbers and class size during the spring of 2015, which were my control group, were smaller, averaging just over thirty students per class ranging from twenty-six to thirty-four students for my five classes. Our district has decided that Chemistry should be offered as a freshman class. These classes do have a few sophomores, juniors and seniors.

Most students, therefore, are taking Algebra I for the first semester and Algebra II in the second semester. The Chemistry classroom is often ahead of the Algebra classrooms in terms of applying basic algebraic problem solving skills. Hence, most will learn Algebra in Chemistry class prior to these concepts being introduced in their formal math training.

Students in my chemistry classes have experienced difficulty with understanding concepts and problem solving. This investigation was conducted in order to determine if comprehension and application could be enhanced through inquiry based learning. Additionally, student attitudes regarding chemistry and the learning environment were observed and measured.

Project Background

During the 2014-2015 school year, I polled students to determine where they struggled most in chemistry and how the best learned in the science classroom. I found that the majority wanted more hands on activities, had difficulty with problem solving, and did not understand the conceptual ideas that supported the problems they needed to solve. Inquiry based learning supported by active learning strategies and guided Socratic questioning have previously allowed students to learn through direct observation and experience with minimal instructor intervention. Based on student feedback and research, I decided to transition the delivery of material and instruction in my Chemistry classrooms. Delivery was shifted from a lecture based approach to an approach that was inquiry driven. The hope was that benefits of this approach for the student would include a more thorough understanding of concepts, of the scientific method and would peak a greater interest and involvement in the Chemistry curriculum.

The goals of this project are for students to learn how to apply problem solving strategies and to analyze information allowing them to draw conclusions. Data gathered throughout the experimental year was compared against student data from the previous year which was the control group. This was done in order to ascertain if inquiry based learning was more effective. Research questions that were addressed included:

- Do problem solving abilities improve through inquiry based lessons?
- Will inquiry based learning enhance student comprehension improve performance?
- How do student's attitudes about science change in an inquiry based classroom?

Through inquiry based learning, I believed that my students would be able to make better connections between conceptual information and real world application. It was also my hope that these connections would better serve them in improving their problem solving abilities and with retention.

CONCEPTUAL FRAMEWORK

The methods in which students are taught play an integral part in their success. Students who are interested in learning will understand concepts more effectively and with more depth than their counterparts. Lovelace and Brickman state that the best indicator of success for students in the science classroom are their attitudes about learning (2013). Inquiry based learning was the instrument used in this study to provide greater interest and involvement from the students. Building off of the investigative work of others, we can continue to ascertain the benefits of inquiry based education. The inquiry

learning model utilizes hands-on activities as a way to motivate and engage students while teaching concepts. It stresses the development of knowledge in individuals through active thinking (Minner, Levy & Century, 2010).

Most students have experience with the direct instruction teaching approach. Classes are lecture based and learning is facilitated by the instructor. This method of teaching implies that lectures are given in class and the lecture is often the first time students are exposed to material. Students are given practice problems or activities to help reinforce concepts taught by the instructor and are eventually tested on their knowledge (Jensen, 2015). This method places the responsibility of learning on the teacher and his or her ability to deliver the material and keep students motivated. Arguments can be made that an advantage to this approach is that students clearly understand objectives and goals (Jensen, 2015). Current educational practices, according to Sesen and Tarhan (2010), have been moving away from direct instruction. The “teacher as an information-giver to passive students appears outdated and active learning methods requiring actively participating students have begun to take more interest to help students,” (p. 2625).

Current educational literature suggests that inquiry based learning provides a richer educational experience for the learner. Studies over thirty years have lead us to believe that the inquiry based learning model is a more effective learning platform than other passive types of teaching methods (Struyven, 2005). The inquiry learning approach is characterized by a focus on concepts that are connected, engaging students in activities that allow development of ideas based on outcomes, an emphasis of learning methods

which test hypotheses and the belief that content and processes are components that reinforce learning (Michael, 2006). This type of learning is student driven as opposed to direct instruction which is driven by the teacher. Students work through the experiment, analyze information and make determinations based on observations. Through this process, they are able to understand from first hand practice how and why things happen in the physical world.

In the science classroom, labs are an essential component to learning. Minner, Levy and Century (2010) believe that utilization of, “hands-on experiences with scientific or natural phenomena were found to be associated with increased conceptual learning,” (p. 20). The lab experience begins with an observation or the posing of a question. An experiment is then designed to solve the problem. Through inquiry based learning, students are able to verify or refute preconceived beliefs through first hand, hands on experience in the lab (Minner, Levy and Century, 2010). The benefits of inquiry based lessons for learning in the science classroom are many. In a study performed at the University of Georgia, researchers studied students taking an inquiry based non-major Biology course and found statistically that, “inquiry lab students demonstrated small but significant gains in science literacy and science process skills compared to students enrolled in the traditional cookbook labs,” (Brickman, Gormally, Armstrong & Hallar, 2009). Seen and Tarhan (2010) found statistically that, “applications cause a significantly better acquisition of scientific conceptions, and ensure positive attitudes toward chemistry lesson in comparison with traditional instruction,” (p. 16).

Supporting Inquiry Based Learning

The greatest challenge to implementing an inquiry based teaching approach is time. As time is often seen by teachers as a constraint, proper planning and time management are important components that must be considered prior to incorporating the inquiry based learning platform. According to Prince (2004), it is, “important to ensure that lessons are designed around important learning outcomes,” and that they “promote thoughtful engagement” (p. 4). In the chemistry classroom, a vast amount of time is spent in lecture, discussion of concepts and solving problems. In order to facilitate a slower paced learning classroom, a variety of strategies were utilized to help students understand required content. To promote inquiry based learning, I was able to remove time devoted to lecture. During this study, online resources were provided to the students to support their understanding of difficult concepts and to help with problem solving. To better meet the needs of my students, online resources in the form of notes, sample problems and video clips via my teacher web page were provided. Placing responsibility on the students to learn materials that were traditionally taught in the classroom is referred to as a flipped classroom. Fulton (2012) describes the benefits of the flipped classroom, “With class time freed up from lectures, teachers are developing open-ended, cross-curricular projects that actively engage students and bring real-life relevance,” (p. 17). The flipped classroom allowed students to look at notes and return to them as needed, gain additional support when convenient and reinforce their problem solving skills with simple to difficult problem examples.

Inquiry based instruction begins with a question to be answered. Active learning and inquiry based instruction go hand in hand. Prince (2004) explains that active learning is, “always active and usually (but not necessarily) collaborative or cooperative,” (p. 3). Bishop and Verger (2013) go further stating that, “active learning acts as a superset for both peer-assisted and problem-based learning approaches,” (p. 4). They go on to define both active and inquiry classrooms as student centered learning modalities that work well when combined with the flipped classroom.

Student attitude impacts student performance. Research by Struyven (2005) has shown that active learning environments enable students to achieve a deeper understanding. Active learning helps students learn more thoroughly, have a more positive attitude and have a greater ability to overcome perceived misconceptions (Sesion and Tarhan, 2010). In a 2007 study of undergraduate students from over forty colleges and universities, researchers found that ninety-one percent had a positive experience in an active learning environment and that sixty-eight percent reported an increase in science interest (Lopatto, 2007). According to Struyven (2013), students in her active learning study enjoyed variation in assignments, challenging assignments and found a deeper connection between activities and readings. Learning connections are more easily made with active learning building confidence and increasing student satisfaction (Struyven, 2013). This research project combined active learning strategies and a flipped classroom approach in order to enhance the inquiry based learning environment in my Chemistry classes.

Summary

This action research project employed inquiry based learning opportunities in order to determine the impact on student performance and learning. Challenges faced include developing curriculum, providing support outside of the classroom and monitoring depth of understanding within the student population. In this study, I will observe the impact of not only student learning and processing of information but also their confidence level and willingness to work in order to overcome obstacles. I will attempt to lead students where they need to go while allowing them to feel as if they arrived to the right conclusions on their own. Previous studies have shown that inquiry based teaching strategies can help students achieve a more thorough and deeper level of understanding. When delivered with active learning strategies, both the inquiry and guided inquiry approaches have demonstrated success in increased participation, depth of understanding, problem solving abilities, interest in science and success on standardized exams such as the ACT. Time constraints will be minimized by flipping the classroom and by providing traditional support online.

METHODOLOGY

The purpose of this study was to determine the impact of inquiry based learning on student motivation and understanding of chemistry. Students in my chemistry classes have struggled with the application of problem solving strategies and in developing analytical skills that are needed to draw conclusions. The goals for my test sample were to improve comprehension, problem solving ability, attitudes and performance on quizzes and exams. Research, as described above, has shown that motivation is a factor that can

increase the likelihood of success in these areas. This project, through the analysis of select qualitative and quantitative outcomes will determine if these goals are met. Data gathered during the second semester and was compared against student data from the previous school year in order to ascertain if inquiry based learning was more effective than direct instruction.

Participants

Participants in this study were high school students taking Chemistry. Students taking Chemistry in year one were the control group and students taking Chemistry in year two were the experimental group. Approximately one hundred and fifty students were taught each year. Similar demographics exist between the two years in terms of age, race, ability level and gender. I taught primarily freshmen students, age fourteen to fifteen in these classes but had several sophomores, juniors and seniors in each class ranging in age between sixteen to eighteen. During the first year, the control group, my students were 61.5% Caucasian, 22.5% Hispanic, 9.3% Black, 4.6% Asian and 2% other. For the test group the following year, the demographics were

Tools to measure success in problem solving, comprehension, motivation and performance were used to determine the effectiveness of the intervention. Students in the experimental group were required to create labs in order to learn concepts while last year's students learned concepts through direct instruction and predetermined labs. The student breakdown for my classes were as follows in Tables 1 and 2:

Table 1
Student Numbers

	Total Students	Males	Females
Inquiry Learning	155	79	76
Traditional Learning	151	80	71

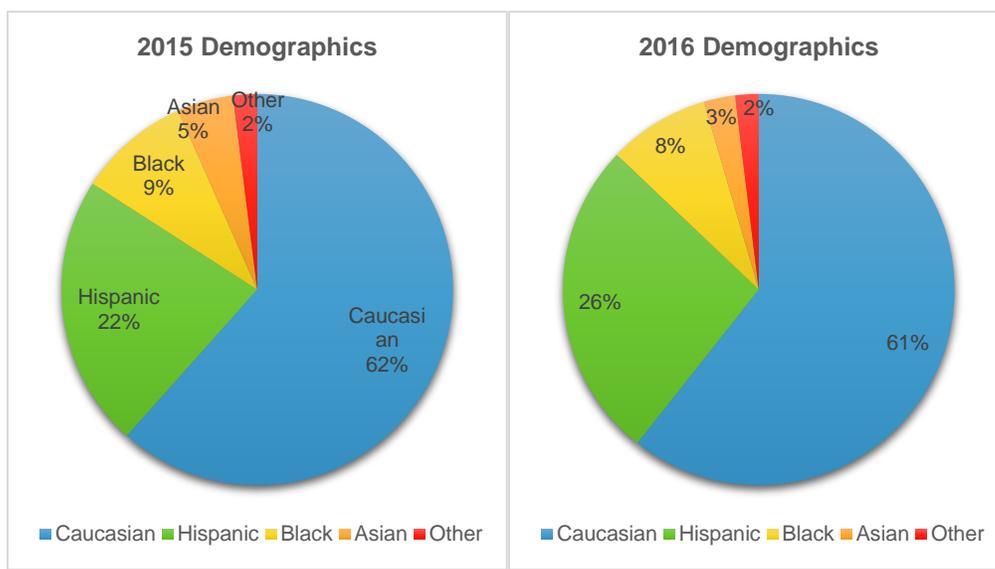


Figure 1. Student demographics.

Intervention

Control group students during the first year were taught primarily through direct instruction. Lecture notes and practice in the form of worksheets with few labs were the primary means of instruction. Time and the amount of material needed to cover within the school year prohibited the inclusion of more than one activity or lab per unit. A shift in teaching philosophy to accommodate inquiry based learning occurred in my science classrooms during the second school year. By providing materials and support online, I found additional time to pursue inquiry based lessons in Chemistry. Having taught inquiry based classes for Physical Science, I had seen students become frustrated from what

they perceived to be a lack of support. I was able to find time to implement student driven active learning strategies which, according Bishop and Verger (2013) did not conflict with the inquiry based learning model. Two units were taught using inquiry methods during the second semester.

To promote inquiry based learning, I removed time devoted to lecture and problem solving. During this study, online resources were provided to the students to support their understanding of difficult concepts and to help with problem solving. To better meet the needs of my students, online resources in the form of notes, sample problems and video clips were provided on my teacher web page. In this study, I observed the impact of not only student learning and processing of information but also their confidence level and willingness to work in order to overcome obstacles. In doing so, I attempted to lead students where they need to go while allowing them to feel as if they arrived to the right conclusions on their own.

For this capstone project, there were numerous tools that were utilized in order to measure performance. Pretests were given to all students to determine knowledge of content and identify misconceptions. Post tests were also given to measure growth during units based on improvement against the pretest. District midterm and final exams provided quantitative data which was used to compare against the previous year's student performance. Per the needs of this study, the learning environment was also monitored. Class discussions and involvement in the labs gave immediate feedback of the overall classroom attitudes towards the lessons. Student surveys were administered to all chem-

istry students at the end of the school year and interviews were conducted following experimental and control units. Three random male and three random female students from each period were interviewed (twelve from each test group) at the end of the final unit. Information gathered from these surveys, observations and interviews have provided qualitative data and helped in monitoring workload and frustration levels. Testing has provided quantitative data. Information obtained over two years compared data from the control group against data from the experimental group.

The first lessons related to stoichiometry and were conducted early in the semester. The control unit was taught via direct instruction and practice the previous year. The experimental group, the following year, was broken into small lab groups that were charged with designing and conducting a lab. The focus of the experimental group's lab was to see how amounts of elements in a compound could be found using whole number ratios. Based on prior knowledge of conservation of mass and balancing equations, students were required to draw and explain how combinations of materials could form new materials while not losing any components. For materials, students were given a quarter cup kidney beans, a quarter cup of pinto beans, a quarter cup of popcorn and an electronic balance. Based on materials given, they were asked to design a model representing a chemical reaction. They then answered questions about the combinations of their elements and the masses that these molecules created. Lab groups were given time to discuss how they would conduct their labs. White boards were used following small group discussion and students presented their ideas to their peers. Students worked with their models representing chemical reactions the following day and found masses using the

electronic balance. In creating combinations of atom, creating molecules and a balanced chemical equation with known masses, students were able to see the Law of Conservation of Mass at work. Additionally, students were able to derive the ratios between molecules and elements in their balanced equation. To end the session, I asked the experimental group students to determine which elements would run out first and how much of the other elements would be left over by mass. Students analyzed their data and presented their calculations to their classmates on the third day.

Inquiry based instruction continued within the stoichiometry unit. Students in the experimental group were required to create a lab that compared theoretical and actual yield. The previous year, with the control group, students took notes and solved problems calculating theoretical yield and percent yield. Prior to solving and practicing these worksheets, the experimental group students were required to develop an experiment measuring the amount of product formed in a chemical reaction. They hypothesized how much product would be produced using stoichiometry. Prior knowledge led them towards determining the theoretical yield based on the amount of reactants used and the ratio of moles in their balanced chemical equation. Again, students were given a materials list, brainstormed ideas for their lab, presented their ideas to the class and conducted their labs the following day. Chemical reactions produced the actual yield which was measured and compared against the theoretical yield. Discussion ensued on the day after the lab pertaining to the difference in actual and theoretical yield. We discussed why the amounts differed, ways to increase the amount produced and students conducted another experiment to test factors that might increase the yield. The objective of the experiment

was for students to understand the difference between theoretical and actual yield, to compare these values, derive the percent yield and to find ways to increase the actual yield. The control unit was taught via direct instruction and practice. The experimental group began with an inquiry lesson followed by notes at home and practice.

Inquiry investigative learning also helped to facilitate the understanding of gas laws. Students in the experimental group were shown a demonstration of a hot can being placed upside down in cold water and imploding. Based on what they saw, lab groups were given the task of creating three lab activities that would measure the volume of the can before and after implosion. One variable could be changed from the original demonstration. The lab allowed them to study the effects of temperature, pressure and volume in a self-designed experiment. Through completion of this lab, my objective was for students to be able to understand and apply the concepts derived in Charles Law, Boyle's Law and Gay-Lussac's Law. The control unit was taught via direct instruction and practice with the same learning objectives.

DATA AND ANALYSIS

Data sources were utilized and designated to specifically answer the following questions as seen in Table 2.

Table 2
Research Questions and Measurement Tools

Research Question			
Do problem solving abilities improve through inquiry based learning?	Pre & posttests (Unit test)	Midterm Exam	Final Exam
Will inquiry based learning enhance student comprehension and performance?	Pre & posttests (Unit test)	Midterm Exam	Final Exam

Research Question			
How do student attitudes change in an inquiry science based classroom?	Participation in discussion and activities	Student Survey	Student Interviews

Student Learning

Statistical analysis of the pretest and posttest, the midterm exam and the final exam of this study utilized t-tests to compare results from one group to the next. The purpose of this test is to determine differences between the control and experimental groups in this study. All results were found to have a p-value of less than 0.05 which gives a 95% confidence level that there is a measurable difference between the control group and the experimental group in the data sources that were quantitatively measurable. Raw and average normalized gains were calculated from the pretest and posttest averages (gain of averages). According to Hake, the difference between a true normalized gain and a gain of averages is insignificant when dealing with larger numbers as found in this study.

The following is the equation for normalized gain, (Hake, 2002).

Equation 1: Normalized Gains

$$g = \frac{\text{post-test scores} - \text{pretest scores}}{\text{total possible} - \text{pretest scores}}$$

The pretest and posttest scores for each lesson were utilized to compare student knowledge prior to and after each unit. Prior to calculating the normalized gains, differences in the scores for the pretest for both the control group and the experimental group were minimal with a p-value of 0.57 falling out of the significant range. Based on this data, both groups started with the same knowledge base prior to the lessons as seen in Table 3.

Table 3
Average Pretest and Posttest Scores for Inquiry and Traditional Learning Groups

	Stoichiometry		% Yield		Gas Laws	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Inquiry Learning	24%	51%	41%	49%	58%	69%
Traditional Learning	25%	44%	41%	44%	59%	64%

A p-value below 0.05 in each area showed that there was a statistical difference between the pretest and posttest groups in understanding of stoichiometry, percent yield and gas laws. Based on an equal starting point, the posttest data showed a 7-percent difference in learning stoichiometry, a 5-point average difference in percent yield and a five-point average difference in gas law understanding. Data from the posttest scores all support inquiry learning over the traditional methods. This indicates that there was a significant positive difference in favor of inquiry learning in teaching stoichiometry, percent yield and gas laws with inquiry as displayed in Table 4.

Table 4
Pretest and Posttest Normalized Gains

Control Group Lesson	Normalized Gains	Experimental Group Lesson	Normalized Gains
Stoichiometry Lesson	25.3%	Stoichiometry	35.5%
% Yield	5.1%	% Yield	13.6%
Gas Laws	6.4%	Gas Laws	12.4%

Differences in performance from the pretest and posttest (unit test) are shown in Figure 2.

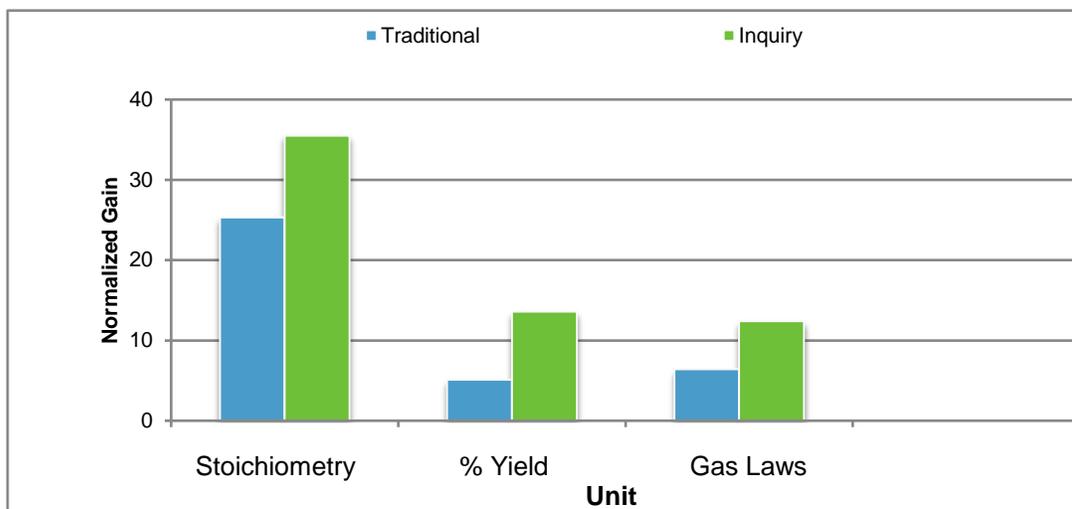


Figure 2. Normalized gain on unit test against the pretest.

A positive correlation with regard to student's learning through inquiry was also evident in their performance on both the midterm and final exams. Range in score included those who did not take the exam as well as those who were exceptional.

Table 5
Midterm and Final Exam Averages

	Midterm Exam	Final Exam
Inquiry Learning	62.4% (SD 0-100)	64.9% (SD 0-100)
Traditional Learning	58.3% SD (0-90)	61.4% (SD 0- 95)

Inquiry learners, on average, performed better than their traditionally taught peers on the midterm exam with calculated p-values for both exams of less than .0001. Traditional learners scored 4.1% lower on the midterm (consisting entirely of stoichiometry and gas law questions) and 3.5% lower on the final exam which (fifty percent stoichiometry and gas law questions) than those who were taught through inquiry (Table 5).

Student Engagement

A significant difference was observed in the classroom between the control group and the experimental group with regard to their involvement in activities and classroom discussion. The experimental group displayed a more positive attitude than the control group and took advantage of their chance to design their own lab. There was a degree of frustration which will be discussed in the survey and interview sections was greatly reduced by the second lesson. Questions were deflected as much as possible in order to have students draw their own conclusions. Classroom discussion answered many questions by filling in gaps and generating deeper understanding for most groups.

There were three class surveys that students completed following each inquiry lesson. These surveys questioned students on their attitude toward the lesson and the class as well as their understanding of the unit. Students were given a series of five questions ranking their enjoyment of the class, the lesson and their understanding on a scale of 1 to 10. Low scores were more positive with a perfect low score of 5 and high scores were negative with a worst possible score being 50. The table below displays these scores and their feeling towards the lessons and class overall.

Table 6
Student Survey Results

	Lesson 1 Score	Positive Attitude	Lesson 2 Score	Positive Attitude	Lesson 3 Score	Positive Attitude	Overall Classroom Attitude
Inquiry Learning	19.8	Neutral	11.2	High	7.1	High	High
Traditional Learning	32.5	Low	27.3	Neutral/Low	12.8	High	Neutral

Again, as low scores were positive, inquiry learning students averaged with a high positive attitude based on the surveys. This means that students were satisfied with the class, the lesson and the learning format while being taught through inquiry more than the traditional way. Students taught traditionally showed more frustration with stoichiometry and percent yield overall but tended to have a better experience and understanding following the gas law unit.

Student interviews were conducted at the beginning of the fourth quarter following the gas law unit. Students were asked about their learning style, what they liked and did not like about the class, where they struggled, about the learning format and their understanding of material. Interviewees were also given an opportunity to give feedback on anything not covered. Students across the board showed frustration with stoichiometry and conversions. The inquiry lab for stoichiometry helped the experimental group in understanding the mole ratio and why it was important but not in understanding the processes involved in problem solving. Both the experimental and control groups expressed negative feeling towards solving these types of problems.

Both groups generally stated that they learned best through hands on activities. A quarter of the experimental group said they preferred direct instruction. Those in the experimental group enjoyed the other two labs and stated that they gained a deeper understanding about gas laws than they would have without the lab. Both groups had an easier time with percent yield and gas laws. Students in both groups enjoyed the last two lessons more than the stoichiometry lessons but many in the experimental group said that this was their favorite lab of the year thus far.

Some students in the experimental group expressed their frustration with not getting immediate answers from me and with their lab partners. Overall, the control group wanted more hands on activities and a few of the experimental group preferred direct instruction. Approximately three quarters of those interviewed in the control group (117/151) wanted more hands on learning activities. Figure 3 gives an overview of the measured data from this study.

INTERPRETATION AND CONCLUSION

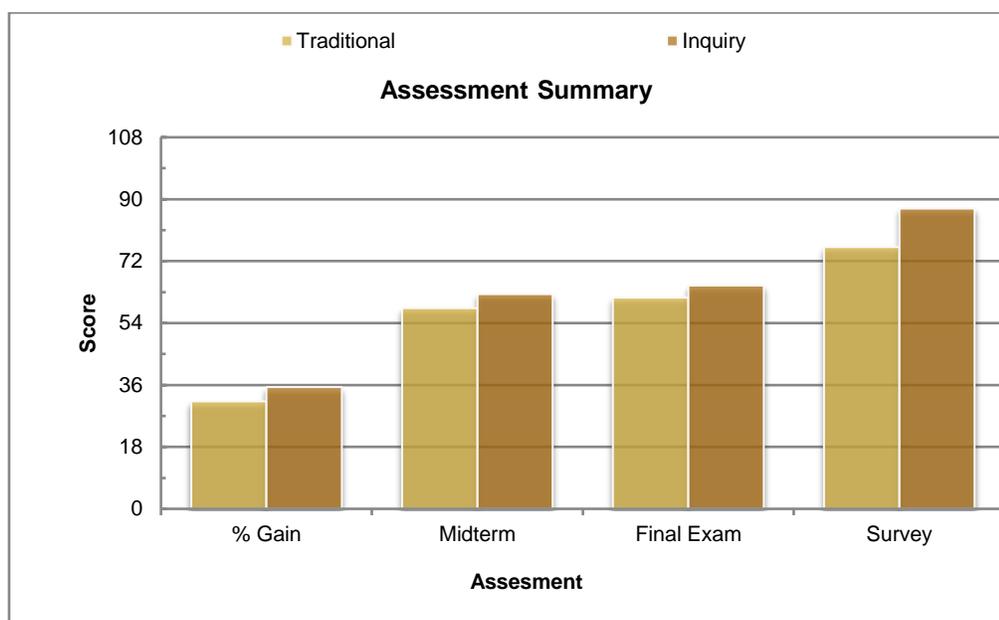


Figure 3. Results overview.

The type of instruction provided by a teacher can have a significant impact on the learning experience of students. This is evident when comparing inquiry based instruction and traditional lecture based instruction in the science classroom.

Data from this study pointed towards a favorable shift in attitudes of chemistry through inquiry instruction when compared to traditional instruction. Additionally, there

was a significant gain in performance on district exams and improvement in problem solving ability as demonstrated on pretests and posttests (unit tests) between the control and experimental groups. Research by has shown that inquiry based education produces positive results. By taking charge of their education, students gain a sense of accomplishment and confidence that was lacking by those who were taught in a traditional manner.

The data gathered during this investigation supports literature stating that student who learn through inquiry based lessons perform better and enjoy science more than peers learning in a traditional manner. Seen and Tarhan (2010) found that, “applications cause a significantly better acquisition of scientific conceptions, and ensure positive attitudes toward chemistry lessons in comparison with traditional instruction,” (p. 16). Minner, Levy and Century (2010) believe that utilization of, “hands-on experiences with scientific or natural phenomena were found to be associated with increased conceptual learning,” (p. 20). Attitude and performance both improved with the application of inquiry based lessons. The data gathered in this study further validates the work and conclusions of others who have found inquiry to be a more effective method of educating students than the traditional lecture based approach.

After teaching for twelve years, it becomes easy to rely on methods and lessons that you have developed previously. A teacher’s responsibility to his or her students mandates that time to plan is essential in order to best reach their students. Additionally, it is necessary modify the assignments as needed during the lesson and reflect on the lesson in order to fill in any gaps in instruction. Inquiry based learning during this investigation required additional planning time, required that I be in tune with student needs during the

lesson and reflection on the effectiveness of the lesson at the end of each day. As with any new process, additional time and effort are necessary to ensure success before, during and after the lesson. The results from this investigation have shown that teaching using an inquiry approach improve both student performance and student attitude towards learning in the chemistry classroom. I plan to continue to develop and deliver inquiry based lessons in my science classroom. The additional time and effort required for an inquiry based classroom provides a more positive and effective learning environment for the student.

VALUE

I have taught using an inquiry and using a modeling approach in the past. My teaching style has shifted towards a lecture format over the past five years since I began teaching chemistry. Through this study, I have rediscovered the impact of inquiry based education and have found that it can be applied in other science classes other than Physical Science. I plan to continue to stretch my boundaries and use inquiry as I teach Biology classes next year. Inquiry proved to make a positive difference on the attitudes, problem solving ability and overall performance in my Chemistry students. Through this school year, by utilizing inquiry instructional techniques, I was able to improve my teaching by getting my students engaged prior to starting a lesson. As a teacher, we sometimes forget what our students go through. Lecture based instruction, though sometime necessary, is unexciting for both the teacher and the student. This experience has enabled me to understand that, with my guidance, my students can take charge of their own education

and in doing so will be more engaged and will develop a deeper understanding of the material.

REFERENCES CITED

- AZDOE (2014). *Arizona Department of Education* [Website]. Retrieved September 15, 2014, from <http://www.azed.gov/blog/2011/05/12/top-school-district-ranking/>
- Bishop, J.L., Verleger, M. (2013). The Flipped Classroom: A Survey of the Research. *American Society for Engineering Education*, 2013, Atlanta, GA (pp. 1-17).Atlanta, GA.
- Brickman, P. Gormally, C., Armstrong, N. and Hallar, B. (2009). Effects of Inquiry-based Learning on Students' Science Literacy Skills and Confidence. *International Journal for the Scholarship of Teaching and Learning*, 3(2), 1-22.
- Fulton, K (2012). Upside Down and Inside Out: Flip Your Classroom to Improve Student Learning. *Learning & Leading with Technology*, 6, 12-17.
- Hake, R. "Interactive engagement vs. Traditional methods." *American Journal of Physics*. 66.64 (1998).
- husd.org (2015). *Higley Unified School District* [Website]. Retrieved September 15, 2014, from <http://www.husd.org>
- Jansen, J., Kummer, T., Godoy, P. (2015). Improvements from a Flipped Classroom May Simply Be the Fruits of Active Learning. *CBE Life Science Education*, 14(1), 1-12.
- Lopatto, D. (2007). Undergraduate Research Experiences Support Science Career Decisions and Active Learning. *Cell Biology Education*, 6(4), 297–306.
- Lovelace, M., Brickman, P. (2013). Best Practices for Measuring Students' Attitudes Toward Learning Science. *CBE - Life Sciences Education*, 12, 606-617.
- Michael, J (1 December 2006). Where's the Evidence That Active Learning Works?. *Advances in Physiology Education*, 30(4), 159-167.
- Minner, D. Levy, A.J. and Century, J. (2010). Inquiry-based science instruction-what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474–496.
- Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, 93(3), 223-231.
- Sesen, B., Tarhan, L. (2010). Promoting Active Learning In High School Chemistry: Learning Achievement and Attitude. *Procedia Social and Behavioral Sciences*, 2(2), 2625–2630.

Struyven, K. (2005). *The Effects of Student-Activating Teaching/Learning Environments on Student's Perceptions, Student Performance and Pre-Service Teachers' Teaching*. (PhD), Katholieke Universiteit Leuven.

APPENDICES

APPENDIX A
SURVEY QUESTIONS

Survey Questions

1. Rank this course from 1-10 with one being your favorite subject and 10 being your least favorite.
2. Rank this lesson from 1- 10 with 1 being the best lesson this year and 10 being the worst.
3. Rank your frustration with completion of this lab with 1 = not frustrated & 10 = most frustrated.
4. Rank how much you learned from your lab with 1 = the most & 10 = the least.
5. Rank your ability to explain this lesson to a classmate with 1 = easily & 10 = can't explain anything.

Best score = 5

worst score = 50

Lesson 1 Average

2015 32.5

2016 19.8

Lesson 2 Average

2015 27.3

2016 11.2

Lesson 3 Average

2015 12.8

2016 7.1

APPENDIX B
INTERVIEW QUESTIONS

Interview questions - Control

1. How do you best learn?
2. Did you have any misconceptions prior to this unit- if so, what were they?
3. What did you like about how we learned in this unit?
4. What didn't you like about how the information was taught?
5. Were the labs in this unit helpful in helping your understanding?
6. Did you feel more comfortable in problem solving from information learned in this lesson?
7. What aspects did you struggle with the most?
8. What would you change, if you could, about learning in this manner?
9. Overall, how was your experience with learning with direct instruction?
10. Do you feel confident that you understand the material from this unit?
11. Is there anything else you want me to know?

Interview questions - Inquiry

1. How do you best learn?
2. Did you have any misconceptions prior to this unit - if so, what were they?
3. When you were given the assignment to create your first lab in the stoichiometry unit, how did you feel about the creation of the lab?
4. What did you like about that lab?
5. What didn't you like about that lab?
6. Did you feel more comfortable in creating experiments in future lessons?
7. Did you feel more comfortable in problem solving from information learned in this lesson?
8. What aspects did you struggle with the most?
9. What would you change, if you could, about learning in this manner?
10. Overall, how was your experience with learning with inquiry?
11. Do you feel confident that you understand the material from this unit?
12. Is there anything else you want me to know?

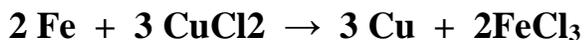
APPENDIX C
STOICHIOMETRY TEST

Stoichiometry Test

Each question is worth 4 points (1 point units, 3 points correct answer)
YOU MUST SHOW WORK FOR CREDIT!



- 1) What is the ratio between moles of **H₂** and moles of **O₂** from the balanced equation above?
- 2) When **21 moles of H₂O** decomposes **how many moles of O₂** are formed?
- 3) Using the equation in #1 **how many g of H₂O** were needed to form **802 g of H₂**?
- 4) How many **grams of Cu** can be formed when **167.4 g of Fe** react with an **200.0 g of CuCl₂**?



APPENDIX D
PERCENT YIELD TEST



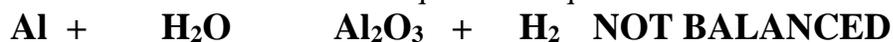
Name: _____

Date: _____ Hour: _____

% Yield Test

- 1) Your parents want you to score at least 90% on this test but you actually score an 84%. What percent of your parent's expectation did you meet?

Use the balanced equation for questions 2-4



- 2) In an experiment, 90 g of H_2 are produced. Stoichiometry that you calculated mathematically says that you should have 118 g. What is your percent yield?

- 3.) 27g of Al reacts with water and forms 145g of aluminum oxide. What is the % yield?

- 4.) When 323 liters of O_2 are produced from a decomposition (electrolysis) reaction of H_2O , how many Liters of H_2O did you start with? Use the equation above.

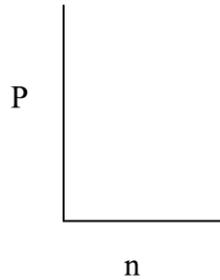
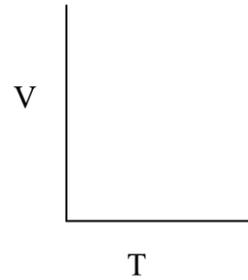
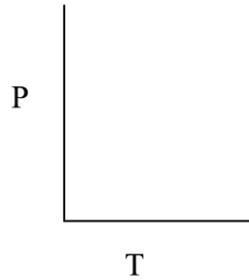
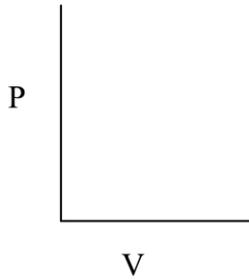
APPENDIX E
GAS LAW TEST

Name: _____

Hour: _____ Date: _____

Gas Law Test

1. Sketch the graph of the following pairs of variables:



2. Would O₂ or N₂ travel faster as a gas and why?

3. A gas sample occupies 200.0 ml at 760 mm Hg. What volume does the gas occupy at 400 mm Hg?

4. A gas has a volume of 472 gallons at a temperature of 27 K. what will be the temperature if the gas is heated until the volume becomes 638 gallons? The pressure of this system is not allowed to change.