THE EFFECT OF LAB BASED INSTRUCTION ON ACT SCIENCE SCORES

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ABSTRACT

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Standardized tests, although unpopular, are required for a multitude of reasons. One of these tests is the ACT. The ACT is a college readiness test that many high school juniors take to gain college admittance. Students throughout the United States are unprepared for this assessment. The average high school junior is three points behind twenty-four, the ACT recommended score, for the science section. The science section focuses on reading text and, interpreting graphs, charts, tables and diagrams with an emphasis on experimental design and relationships among variables. For students to become better at interpreting and understanding scientific graphics they must have vast experience developing their own graphics. The purpose of this study was to provide students the opportunity to generate their own graphics to master interpretation of them on the ACT. According to a t-test the results show that students who are continually exposed to creating graphs are able to understand and locate information from graphs at a significantly faster rate.

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INTRODUCTION

Pictorial representations and graphics or diagrams that represent connections between numbers, points, lines, bars are all around us. We see them everyday in newspapers, online, in textbooks, in the media and especially on standardized tests (McBride 2009). On average, there are 1.38 graphics per page in high school science textbooks and about 1.46 graphics per page in scientific journals (Yeh and McTigue 2009). Graphics are extremely useful to display information quickly and concisely. However, even with this overexposure to visual graphics and data there is still a widespread lack of graph construction and interpretation in science courses (Tairab and Al-Naqbi 2010). With the pressure on students to succeed on standardized tests science teachers need to rethink how they teach graph construction and interpretation in their high school science courses. Standardized tests are not popular with the majority of teachers, students and parents. In fact, students think admission or aptitude tests “focus on trivia, ask tricky questions and are not relevant to what is taught in schools” (Bangert-Drowns et al. 1984). A survey of standardized science tests showed that these tests do not usually measure student’s ability to think, but rather to memorize scientific fact or to read text and graphics quickly (Morgenstern and Renner 1984). Despite the unpopularity for these standardized tests they are here to stay. One common standardized test is the American College Test or ACT. This test is considered to be a college readiness test because the ACT focuses on deep problem solving skills and application of knowledge of learned skills in the form of data manipulation, and information analysis (ACT Inc. 1996). The ACT is usually given to high school juniors or seniors and it is comprised of 5 sections: English, Math, Reading, Science and Writing.

Each of the four multiple-choice sections (English, Math, Reading, Science) are out of 36 possible points. These four multiple-choice tests are then averaged to calculate an ACT composite score- also out of 36 possible points. The writing score is out of a possible 12 points. Each section of the ACT has a distinct score that is deems test takers as college ready by the ACT organization. The college ready score for the English section is an 18, the math and reading sections have a college ready score of 22, the science has a college ready score of 23 and the writing section does not have a readiness score (ACT 2015).

The English section of the ACT focuses on sentence structure, grammar, author's purpose and writing style. The math section of the ACT requires students to memorize and then utilize common math formulas including simplistic math all the way up to trigonomic functions. The reading section focuses on reading comprehension of four different passages types: prose fiction, social studies, humanities, and natural sciences. The science section focuses on reading and interpreting graphs, tables, and other visual representations of collected data. In addition, the ACT Science test also expects student to compare and contrast experimental designs, methods and conflicting viewpoints of different scientists (ACT Inc. 1996). The ACT board describes this portion of the ACT as follows: "measures the interpretation, analysis, evaluation, reasoning, and problem-solving skills required in the natural sciences" (ACT Inc. 2015). The science portion clearly involves science content, unlike the other ACT subsections. However, memorization of facts is not required because all required information is presented to the students (Allensworth et al. 2008).

For students to be successful on the science portion of the ACT they must be able to interpret and understand graphs in detail. The ability to decode information presented in graphs was deemed "graphicacy" in 1965. Graphicacy can be explained as "the ability to read graphs, defining it as proficiency in understanding quantitative phenomena that are presented in a graphical way" (Friel et al. 1996). Due to the unique nature of the ACT science test, and its focus on graphicacy, in addition to the popular use of graphics in all print including journals, texts, and media, the science portion of the ACT is the focus of this study.

It has been very apparent over the last decade that our current Michigan high school students are underprepared for the ACT, despite their desire to succeed. In 2008, when the entire state of Michigan required every junior to take the ACT, the number of students that were college ready in all subject areas was only 14.8%. In 2013 the number of Michigan juniors that were college ready in all subject areas was 18.1% Finally, in 2014 the number of Michigan juniors that were college ready in all subject areas was 17.8% while their average ACT score was 19.8 (Higgins et al. 2014). The Michigan average for juniors in 2014 on the science section was 20.4, which is significantly lower than the state cut scores by about three full points (ACT 2015).

Looking specifically at Grand Ledge Public High School in 2014, the mean ACT composite score of the tested juniors was a 20.6. This average is only about one point below the state cut-score. Grand Ledge High School's English score was 20.0, which is about 2 points above the state cut-score. The juniors' math average was a 20.1- almost two full points below the state cut-score. Their reading average was a 20.7, again almost 2 full points below the cut-score. Finally, the juniors had an average of 21.1 on the ACT science section, which is approximately 1.9 points below the state cut-score (Michigan Department of Education 2015). The low scores at Grand Ledge High School are unusual because the school is well known for its academic achievement. These results have led administrators and teachers to ask the following question: "what can we do as a school to help students improve their ACT scores?"

According to Slack and Porter (1980), these standardized or Scholastic Aptitude Test scores can be substantially influenced as a result of coaching from educators. Coaching is defined as "utilization of an aid or tool by a test-taker to acquire information and techniques for the purpose of attaining the highest score possible on a test" (Stockwell et al. 1991). Standardized test coaching usually involves a lot of repetitive practice, simple test-taking strategies, and exposure to the testing format and old tests.

However, continued poor performance on the ACT shows that current ACT preparation is not working. Currently students are focusing on the ACT as a last minute sprint, but this type of preparation does little to no good. The ACT requires years of developing and applying learned skills (Allensworth et al. 2008). One study conducted in the Chicago School District discovered that the average English teacher spent roughly 60% of their students' junior year preparing for the ACT and about 40% of math and science classes involve some kind of ACT preparation. This preparation time was usually designated for practice problems, practice tests, and test-taking strategies. Despite these efforts Chicago Public Schools saw a minimal and insignificant increase in ACT scores. These small improvements on standardized tests were attributed to increased student familiarity of the passages and timing, which reduce student anxiety and nervousness (Fallows 1980).

Poor test results, despite preparation, have caused teachers to wonder how they can actually impact their students' performance on standardized tests, like the ACT, by coaching or teaching if practicing the test is not enough. The answer lies in the type of practice and activities completed by students. A number of factors can influence the increase in ACT scores including the objectives of the activities or the approach taken by the teacher in addition to the students' educational background (Scholes and Lain 1997). When teacher coaching occurs in addition to cooperative learning between students a significant increase in scores can be expected (Din and Soldan 2001). Therefore, just practicing for ACT or providing general coaching is not enough to produce improvement in ACT Science scores. Instead co-learning and activity based instruction are important for gains to occur.

To better prepare high school students for the ACT Science assessment teachers must focus on analyzing data and graph interpretation. It is extremely important that students can interpret and understand graphs on the ACT Science test. Therefore, science teachers must provide direct and explicit graph instruction prior to the ACT. This is because "graph instruction with a context of data analysis may promote a high level of graph comprehension that includes flexible, fluid, and generalizable understanding of graphs and their uses" (Friel and Bright 2001). However, many high school teachers often neglect graphic instruction and construction because it is assumed that pictures and graphics are self-explanatory and require little if any clarification (Malmitsa 2008). However, research shows that high school students have not acquired graphing skills and they are inadequate at using and interpreting graphs (McKenzie and Padilla 1986). When teachers develop materials to address this inadequacy they must first recognize the factors that affect student understanding of graphics.

When deciphering tables and graphs there are a multitude of factors that determine a student's performance. One of these factors is the complexity of data representation. For example, tables are usually easier and more quickly interpreted by students. Other factors that influence data interpretation include the number of points, displays, configuration and trends within the data. One thing that can influence success with these complex figures is the student's experience, which can provide specific skills to better understand and read graphics (Meyer et al. 1997). Not only is more graph experience needed but students need to be provided with real world applications. This is extremely important, because having real life context of graphs helps students learn significantly better (McBride 2009). When implementing real-life graph experiences the graph fluency of students improve.

For students to be fluent in graphic interpretation teachers must focus on three levels of graphicacy. The first level focuses on extracting data from a graph. This level of graphicacy is usually much easier for students than determining relationships between variables. The second level of graphicacy is of medium difficulty to students, because it usually involves interpolating between points in the graph and determining relationships in presented data. Finally, the third and most challenging level of graphicacy, involves extrapolation from the data and further interpretation of the relationships identified in the graph (Friel et al. 1996).

The first level of graphicacy, being able to quickly locate information on a graph, is commonly assessed on the ACT Science section. These questions are embedded throughout all three distinct science passage types: Data Representation, Research Summary and Conflicting Hypotheses. These low-level questions are fairly easy to answer but are commonly missed by ACT test takers. The most common mistake for students on these questions occurs due to a lack of math knowledge, reading or language errors, reading graph axes or scales wrong. These mistakes are usually due to rushing (Friel and Bright 2001).

Tier two (medium level questions) on the ACT Science portion require interpolation or determining relationships between data sets. These questions are also embedded throughout the three passage types on the Science ACT. These tier two questions seem to be more challenging for students, because students must make inferences, generalize or predict further outcomes from the data (Friel and Bright 2001). *Generalizing* and *predicting* usually requires higher-level thinking and problem solving skills. This type of problem solving requires students to draw multiple pieces of information from the passage or graphs. Anytime more than one piece of information found within a table or graph is needed to answer a question student performance declines (Bestgen 1990).

To reach the third level of graphicacy it is extremely important for students to be able to translate information between multiple graphics including tables, line graphs, bar graphs, and extrapolate information. This involves rearranging material, re-sorting it and extrapolating data, requiring even more complexity for test-takers. Tier three graphicacy is difficult and requires students to have logical reasoning ability, which is not obtained until a high school level (Wolff and McGinn 1996). Therefore, during a student's high school stay they must be given deliberate experience and training with graphs and other visual representations. It is important to know that it is not enough to only practice graphing with interpreting. Students will not learn to use graphics with repeated exposure to them (Leinhardt et al. 1990).

Instead, students need to "actively participate in them (graphs) with their peers" (Wolff and McGinn 1996). Students learn graphing much better through their own engagement of graphing tasks (Leinhardt et al. 1990). This is because students who are actively engaged in graphing activities construct their own knowledge and increase understanding through participation (Patke 2013). Therefore, for student improvement to occur, in all three tiers of graphicacy, specific scaffolded instruction with continuous and diverse experience with graphics is required in the classroom. Students need deliberate practice with the following aspects of graphing: interpreting and highlighting trends, reading values, identifying tasks, and constructing graphs (Tairab and Al-Naqbi 2004). Of these items the most important aspect is graph construction- students must physically create graphs. Graph construction is much more complex, building on interpretation and requiring much deeper understanding of the presented material. To construct graphs students must generate new data that is not provided by doing investigation (Leinhardt et al. 1990).

Generating this new information helps students comprehend relationships better. Constructing graphs also requires students to develop higher levels of cognitive engagement. The reason for this is that graph construction is very similar to putting together a puzzle which develops student understanding of relatedness of the different variables being tested (Berg and Smith 1994). Finally, graph construction allows students to make predictions between variables, which permits students to understand and quantify relationships significantly better. Being able to quantify relationships is an integral part of experimentation in the scientific community (McKenzie and Padilla 1986).

Students will be most successful with graph interpretation and construction when graphing is paired with scientific inquiry and hands-on science (Yeh and McTigue 2009). Hands-on or inquiry science has a variety of positive effects on student learning. For example, hands-on or inquiry science improves student attendance, work ethic, and attitude towards the material. All of these outcomes lead to better student success on standardized tests (Tretter and Jones 2003). Inquiry learning also strengthens cognitive ability, provides students with a deeper appreciation of science and helps them understand the fundamentals of science (Powell 2010). Finally, inquiry or hands-on learning helps students retain information for longer periods of time and aids students with logical approaches to answering new questions with little background information provided (Patke 2013).

Not only does hands-on inquiry learning engage students and build their graphicacy it helps students understand the scientific process better. It also provides motivation for utilizing graphs and identifying the practical applications for graphs in daily life (Bestgen 1980). Part of the ACT Science test requires students to critically think about presented scientific research, experimental design and the validity of collected data. In fact, two of the three ACT science passage types (research summary and conflicting hypothesis), include concepts that require students to identify proper scientific approach, experimental design and data analysis. This part of the Science ACT is best prepared for by actually doing scientific laboratories, which involve "using tools to gather, analyze, and interpret data, proposing answers, explanations and predictions (Turner and Rios 2008)." Inquiry or hands-on science instruction gives students the experience conducting their own scientific experiments, making them better prepared to evaluate other scientific experiments and notice inconsistencies or irregularities in experimental design (Tretter and Jones. 2003).

With the increasing availability of technological information it is imperative that students improve their graphicacy so they have insight to ask critical questions when presented data (Aoyama 2007). Research shows that last minute prepping and learning general ACT strategies is not significantly helpful for students on the ACT Science test (Allensworth et al. 2008). Improvement on the ACT Science portion occurs when there is deliberate and direct instruction on graphics. Furthermore, practice and construction of graphs and other visual aids is the best method to positively influence students' ACT Science scores. It seems that the most growth occurs whens students are actively engaged in graphing activities. The purpose of this study is to determine if participating in graphing activities, including construction and interpretation practice, does improve ACT science scores in high school students.

GOALS AND OBJECTIVES

While teaching the science rotation of the ACT Skills class there were two major goals. The first goal was to increase the ACT student's graphicacy including their ability to create and understand science information in the form of graphical representations such as tables, single-line graphs, bar graphs, and multi-line graphs. The second goal was to increase the students' ACT science score.

The objectives for the twenty-one day ACT rotation included: 1) students would be able to construct simple graphs and be able to answer questions about their constructed graphs; 2) students would be able to quickly locate information that is presented in any type of graph; 3) Students would be able to identify the relationships between multiple sets of data in terms of direct vs. indirect or inverse relationships; 4) Students would be able to skim the science ACT passages when necessary to pull out important information when it is not directly included in the visual graphics; 5) Students would be able to summarize the information in a provided passage in their own words.

Three different methods to were implemented to achieve these objectives. First, the ACT Science section was broken down into mini-lessons. A particular graphic representation was picked that was common on the ACT including tables, bar graphs, single-line graphs, and multi-line graphs which were briefly lectured on methodology on how to approach each type of graphical representation. Second, hands on laboratory activities were incorporated allowing students to collect their own data and then construct ACT like visual aids. The students were expected to be more engaged in their own learning allowing for them to reach a higher level of understanding. Third, students were exposed to many former ACT passages that included the same type of graphical representation and which had them analyze the passages in the same ways they did with their own collected data. The expectation was that with all of this practice with constructing and reading graphs the students would be able to increase their ACT Science scores and graphicacy.

CLASS DESCRIPTION AND DEMOGRAPHICS

This study was administered at Grand Ledge High School within the Grand Ledge Public Schools District in Grand Ledge, Michigan. Grand Ledge is a moderately sized suburban/rural school district located approximately 12 miles west of downtown Lansing, Michigan. Grand Ledge Public schools cover an area of 125 square miles, which includes Delta Mills, Mulliken, Wacousta, Eagle and Delta Township. The majority of the district lies in Eaton County but also includes parts of Ionia and Clinton Counties. These communities are made up of a population of about 31,000. As a result of this large and spread out area of residents, there are many different professions within the community. Many individuals commute from Grand Ledge to work in Lansing, East Lansing and other towns nearby. There is a mixture of professional, blue-collar workers, and farmers in this area. The population of Grand Ledge consists of 52% women and 48% men. The median age of the population is 39. The median income for a household is $47,043, while the median income for a family is approximately $55,000. About 6.3% of the families of the population live below the poverty line.

Grand Ledge school district was founded in 1886. Grand Ledge Public Schools consist of one early childhood (Holbrook Early Childhood Center) and kindergarten center (Neff Kindergarten Center), four elementary schools (Wacousta Elementary, Beagle Elementary, Delta Center Elementary, and Willow Ridge Elementary), one middle school (Hayes) and one high school. In total, roughly 5,300 students attend Grand Ledge Public Schools with approximately 1,700 students at the high school. The student population is 88 percent Caucasian, 5.9 percent African American, 3.2 percent Hispanic, 2.1 percent Asian, and 0.4 percent of other ethnicity. The high school has a graduation rate of 88.97 percent and of the students that graduate 90 percent of them continue education after high school. Within the district about 26 percent of the student population receives free or reduced lunch. 12.6% of the population at Grand Ledge qualifies for disability services. Grand Ledge Public Schools have a teacher to student ratio of about twenty-four students to one teacher.

As a result of the 2013 and 2014 ACT results, Grand Ledge High School has been deemed a red district by the state of Michigan's accountability scorecard (MI School Data 2015). A red district is one that does not meet their targeted learning goals appropriated by the state of Michigan. In response to the red school status, the administration at Grand Ledge High School decided to implement an ACT Skills class for the 2014-2015 school year. The expectation for this course was to prepare students for the ACT and improve their ACT scores in all subtests. All Grand Ledge High School sophomores were given an ACT practice test in the spring of 2014. Any student that received an ACT composite score between a 12 and 20 was required to take the ACT skill class during the following year (2014-2015). Students were removed from one of their chosen elective courses and involuntarily placed into this ACT Skills course. The ACT Skills class consists of three seventeen-day rotations. One rotation covered English and reading strategies involving lots of practice and direct instruction from a certified English teacher. The second rotation focused on math preparation taught by a certified math teacher. The final rotation introduced the science-reasoning subtest and focused on graph interpretation and construction, taught by a certified science teacher. The ACT Skills class was considered a credit/no credit class, in which students had to complete all coursework to receive credit in the class. At the end of the trimester students were given a full-length ACT post-test and could select a letter grade based on their post-test composite score. A composite score of a 21 or above would allow a student to receive a letter grade of an A. A 19 or 20 on the post-test would grant a student a letter grade of a B and if a student scored a 17 or 18 they could choose a C. Finally, any student receiving a 16 or below would only gain credit if they completed all of their coursework. In this study we will focus on the results of the three-week science rotation only.

The study was conducted in six different classes of about twenty students each between September 2014 and December 2014. There were 72 students involved in this study, all of whom signed the *Parent Consent and Student Assent Form* (Appendix A). This group of students represented approximately 4% of the high school population. 100 percent of these seventy-two students were juniors. This student population was targeted because they did not meet the state cut score of an ACT composite score of 21.25 during their spring 2014 pre-test. The ACT composite score is an average score of all subsections of the ACT including- English, Math, Reading and Science. The state has determined that a student scoring 23 and over on the ACT Science portion is considered college ready. Despite none of these students meeting the state cut score for ACT composite, two students in the study were already college ready for the science subsection of the ACT. Of the 72 students participating in the study nine of them were special education students, which is thirteen percent of the student population. 55 percent of the students were males and 45 percent were females. This group of individuals is fairly representative of the entire school population.

IMPLEMENTATION

To begin the ACT Science rotation each student in all six classes took an ACT Science pre-test which can be found in the supplemental material document C. The pre-test was proctored exactly like the actual ACT. It consisted of 40 questions, and 35 minutes was allotted for the students to finish the pre-test. Students were asked to try their best and were not given any help or clarification on any questions. After the initial pre-test the ACT Science unit began.

The focus of the science rotation was graph interpretation, understanding and construction. Activities included ACT practice sets, vocabulary building, and labs including data collection followed by graph construction (Supplemental Materials C). During each mini-unit students were presented with a lecture that included explicit instructions on how to read and interpret each type of visual representation (i.e. tables, bar graphs, etc). After the lecture students participated in one or more hands-on laboratories. These laboratories included pre-formulated ACT like follow-up questions, which focused on all three tiers of graphicacy with a major focus on relationships between variables. Following these laboratories each student worked individually on one or more practice ACT passages that focused on the same type of visual representation (i.e. bar graphs). Students were then given solutions to each ACT practice set. After these activities containing a specific learning target, the students were given a quiz over that type of visual graphic. The quizzes (Supplemental materials A) contained the former ACT passages the students practiced, but with completely different questions. Once the quiz was completed and corrected the next mini-unit began. In addition to these mini-units throughout the three-week science rotation, typical ACT science vocabulary was embedded into the curriculum.

Table One specifically outlines the activities and objectives presented on each day of the ACT Science rotation.

Table 1: Summary of Daily Activities During ACT Science Rotation

Day	Activities (Supplemental Appendix Location)	Description of Graphing Activity	Objectives Covered
1	- ACT Pre-Test (C1)	N/A	N/A
2	- Analyze Pre-Test (C6) - General ACT Strategy Notes	N/A	- Locating information quickly
3	- Table Strategy Notes - pH Lab (A1) - ACT Tables Practice Set 1 (A2)	Students construct a table including qualitative and quantitative data	- Construct simple graphs - Identify relationships between data sets
4	- Student Survey Lab (A3) - ACT Tables Practice Set 2 (A4)	Students construct a table including qualitative and quantitative data	- Construct simple graphs - Identify relationships between data sets
5	- ACT Table Quiz (C2) - Bar Graph Strategy Notes	N/A	- Locating information quickly - Identify relationships between data sets
6	- Pendulum Lab (A5) - ACT Bar Graph Practice 1 (A6) - ACT Bar Graph Practice 2 (A7)	Students conduct an online simulation of pendulums then construct a data table and then create a bar graph comparing two different variables- pendulum length and pendulum weight with respect to period	- Construct simple graphs - Identify relationships between data sets

Table 1 (cont'd)

7	- Bar Graph Quiz (C3) - Single-Line Graph Strategy Notes	N/A	- Locating information quickly - Identify relationships between data sets
8	- Bowling Ball Lab (A8) - Single-Line Graph Practice 1 (A9) - Single-Line Graph Practice 2 (A10)	Students construct a table and create a single line graph comparing distance over time	- Construct simple graphs - Identify relationships between data sets
9	- Single-Line Graph Practice Quiz (C4) - Start Grow Toy Lab (A11)	Students begin constructing a table with quantitative measurements	- Locating information quickly - Construct simple graphs - Identify relationships between data sets
10	- Multi-Line Graph Strategy Notes - ACT Multi-Line Graph Practice 1 (A12)	N/A	- Locating information quickly - Identify relationships between data sets
11	- NOAA Weather Graphing Activity (A13) - ACT Multi-Line Graph Practice 2 (A14)	Students use a data table to construct a 3-line graph with 3 different y-axes.	- Construct simple graphs - Identify relationships between data sets - Locating information quickly

Table 1 (cont'd)

12	- Finish Grow Toy Lab (A11) - ACT Multi-Line Graph Practice 3 (A15)	Students finish completing a data table and then complete 3 different multi-line graphs comparing 3 different variables to solution size in mL	- Construct simple graphs - Identify relationships between data sets - Locating information quickly
13	- Multi-Line Graph Mini Quiz (C4)	N/A	- Identify relationships between data sets - Locating information quickly
14	- Conflicting Hypothesis Strategy Notes - Conflicting Hypothesis Practice 1 (A16)	N/A	- Skim ACT passage - Summarize information - Locating information quickly - Identifying relationships between data sets
15	- Conflicting Hypothesis Practice 2 (A17)	N/A	- Skim ACT passage - Summarize information - Locating information quickly - Identifying relationships between data sets

Table 1 (cont'd)

16	- ACT Post-Test (C5)	N/A	- Skim ACT passage - Summarize information - Locating information quickly - Identifying relationships between data sets
17	- Analyze Post-Test (C6) -Anonymous Student Survey (C7)	N/A	N/A

REVIEW OF GRAPHING ACTIVITIES

All six classes were presented the same activities over their ACT Science rotations. In total there were six hands-on labs used during the seventeen-day unit. The first two activities targeted construction of data tables. The first lab (Supplemental Materials A1) required students to collect data on different types of solutions. Qualitative data were collected including physical observations such as odor, color, and texture. Quantitative data were also collected including: pH, the solution's effect on red and blue litmus paper. The second activity (Supplemental Materials A3) was a student measurement survey. Within this activity each student worked in groups of three or four and collected qualitative data including: t-shirt color, student name, hair length (short, medium, or long), etc. and quantitative data including: arm span, height (cm), age, etc. All of these data were collected and placed into one large data table.

The third activity (Supplemental Materials A5) targeted bar graphs. Students completed an online simulation to determine what affected the pendulum's period. This activity used the PhET Interactive Simulations pendulum simulator developed by the University of Colorado (http://phet.colorado.edu/sims/pendulum-lab/pendulum-lab_en.html). Students altered two different variables: pendulum length and mass. Students constructed a data table and then completed two different bar graphs comparing a pendulum's period to the height in the first graph and a pendulum's period to the mass in the second graph.

The fourth activity (Supplemental Materials A8) addressed single-line graph practice. Students worked as a group in the hallway to record the time it took for a bowling ball to travel down a hallway. Each student stood at a different tile in the hallway and recorded the amount of time it took for the bowling ball to cross their tile. Students recorded these data into a table and then constructed two separate single-line graphs. The first line graph compared the distance the bowling ball travelled to the time, while the second line graph compared the number of tiles passed to the travel time.

The fifth and sixth activities targeted strategies to generate a multi-line graph. The fifth activity (Supplemental Materials A11) required students to soak different “grow” toys in different solution volumes and types over 48 hours to determine the percentage of increase in weight, width and length. Students collected these three measurements before and after soaking the grow toys. Students then had to calculate the percentage of increase in size by comparing their toy’s measurements before and after including the masses, widths and lengths. All of this information was collected and placed into one data table. Students then graphed these data onto three different graphs, one comparing solution volume to the percentage of mass increase, another comparing solution volume to the percentage of width increase, and their last graph comparing solution volume to the percentage of length increase. Each of these graphs had three different lines one for each type of solution (sugar water, distilled water and tap water). The sixth and final lab activity (Supplemental Materials A13) required students to construct a multi-line graph from pre-existing data. Each student was given National Oceanic Atmospheric Administration (NOAA) weather data from Lansing during 2013. These data included relative humidity, maximum average temperature and precipitation. Students graphed these data for every month during 2013. This graph was particularly interesting because students needed to construct three lines on the same graph using three different y-axes.

TRACKING STUDENT PROGRESS

Students were tracked regularly throughout the seventeen-day science rotation. Students submitted their labs after completing them so they could be photocopied for use in this study. The original labs were then returned to students and were corrected, in detail, during class. Students were expected to correct their work and fix any mistakes that they made with the follow-up questions or graph construction. Students were required to keep all of their materials for the course in an ACT binder. To further monitor student progress and class participation students were required to submit their binders two times during the science rotation for a binder check. Student binders were reviewed and scored as credit or no credit and then returned the following day. To receive credit students had to complete all coursework and have corrections written on all of their labs or ACT practice sets. If students did not complete all of their coursework they could not receive credit in the class at all. Of the 72 students included in this study all 72 students received credit for the ACT binders.

ASSESSMENTS

Assessments for the science rotation included one pre-test, four mini-quizzes and one full-length ACT post-test (Supplemental Materials C). The pre-test was an old full-length ACT Science test. The mini-quizzes consisted of two or three former ACT passages that included the targeted visual representations. The first mini-quiz (Supplemental Materials C1) focused on the students' ability to interpret tables, the second (Supplemental Materials C2) focused on bar graphs, the third (Supplemental Materials C3) focused on single-line graphs, and the last mini-quiz (Supplemental Materials C4) focused on multi-line graphs. Despite these post-tests being only a portion of the actual ACT, the scores were calculated using the scored percentages and these were compared to the standard ACT chart (Supplemental Materials C5) and were scored out of 36 possible points. The post-test (Supplemental Materials C6) was identical to the pre-test and also was scored out of 36 possible points.

At the end of the ACT Science rotation an anonymous student survey (Supplemental Materials C7) was administrated. Students were asked a variety of questions about the science rotation. Some of these were general questions that focused on the helpfulness of the ACT Science rotation. Other questions were more specific about what activities were helpful or not. Approximately one third of the students in this study discussed their thoughts about the graphing activities their responses are shown in Table 2 in the data and results section of this paper.

RESULTS AND ANALYSIS

On the first day of the ACT science rotation students were given a pre-test (Supplemental Materials C1) to determine baseline information about their prior ability on the ACT Science section. This pre-test was comprised of a previously used ACT Science section, which contained tables, pictures, bar graphs, single line graphs and multi-line graphs. The ACT science rotation students were given an identical post-test at the conclusion of this section. Their scores were analyzed and a t-test was done with $p = 0.05$.

Figures 1-5 show comparisons of the pre-test data versus the mini-lesson quizzes and the post-test scores for all students who volunteered to participate in the study. Figure 1 compares the ACT Science pre-test scores to the ACT Science post-test scores of all 72 study participants. Figure 2 compares the ACT Science pre-test scores to the tables practice quiz. Figure 3 compares the ACT Science pre-test scores to the bar graph practice quiz. Figure 4 compares the ACT Science pre-test scores to the single-line graph practice quiz. Finally, Figure 5 compares the ACT Science pre-test scores to the multi-line graph practice quiz. All quiz and test averages improved from pre-test to post-test. Tests and quizzes were graded using a standard ACT scale ranking students between 1 and 36 points, Appendix A6 has details on how the ACT score is scaled. A scatter plot was chosen to present data so individual improvement from the pre-test to post-test and mini-lesson quizzes could be seen.

Figure 1: Grand Ledge ACT Science Pre-test and Post-test Results (n=72)

Pre-Test Average= 18.07 Post-Test Average= 20.73

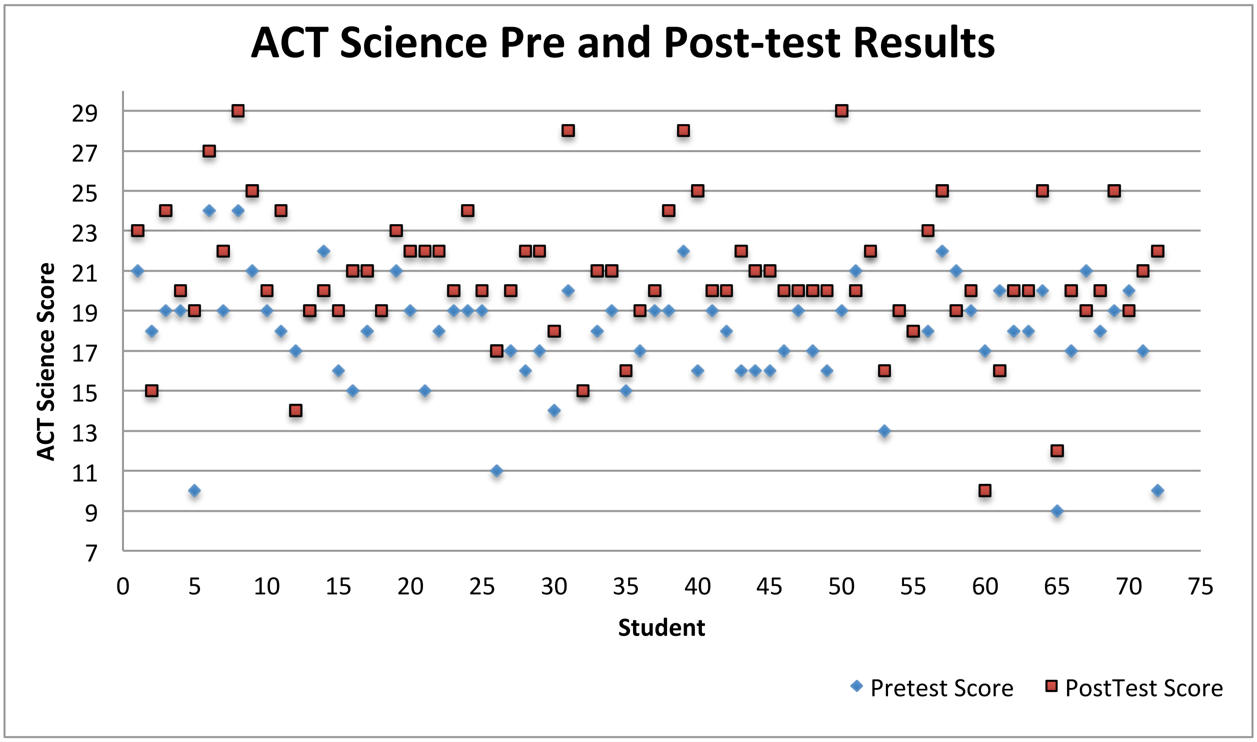

Figure 1 shows that of the 72 students assessed 57 students increased their ACT scores, while nine student's ACT science score decreased (students 2, 12, 14, 51, 58, 60, 61,67 and 70) and six student's ACT science score remained the same (students 13, 18, 32, 52, 54 and 55). Of the 57 students who improved their score twelve students signifiicantly raised their score by six or more points (students: 5, 11, 16, 21, 26, 28, 31, 40, 43, 51, 69, and 72), while nine students only raised their score by one point (students: 4, 10, 23, 25, 35, 37, 41, 47, and 59). As a whole group the average pre-test score was 18.07 while the post-test score was 20.73. This is an increase of 2.66 which is statistically significant according to a t-test (p= 0.05).

Figure 2: Grand Ledge ACT Science Pre-test and Tables Practice Quiz Results (n= 72)

Pre-Test Average= 18.07 Tables Practice Quiz Average= 26.38

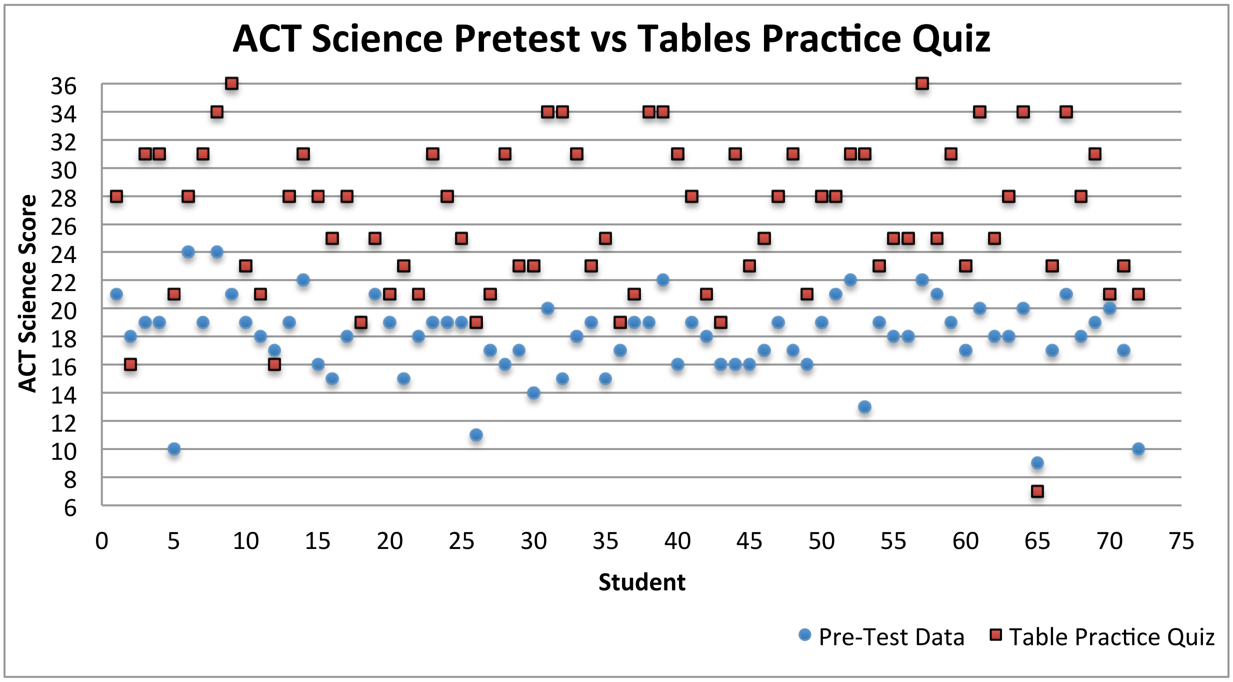

Figure 2 shows that 68 students improved from their pre-test to their tables quiz, three students' scores decreased (students 2, 12 and 65) and only one student's score stayed the same (student 18). Some of the students that improved their scores did so drastically; some students increased their scores by ten or more points. Other students improved their score by only a point or two. As a whole group the average pre-test score was 18.07 while the tables practice score was 26.38. This is an increase of 8.31 which is statistically significant according to a t-test (p= 0.05).

Figure 3: Grand Ledge ACT Science Pre-test and Bar Graph Practice Quiz Results (n=72)

Pre-Test Average= 18.07 Bar Graph Quiz Average: 25.24

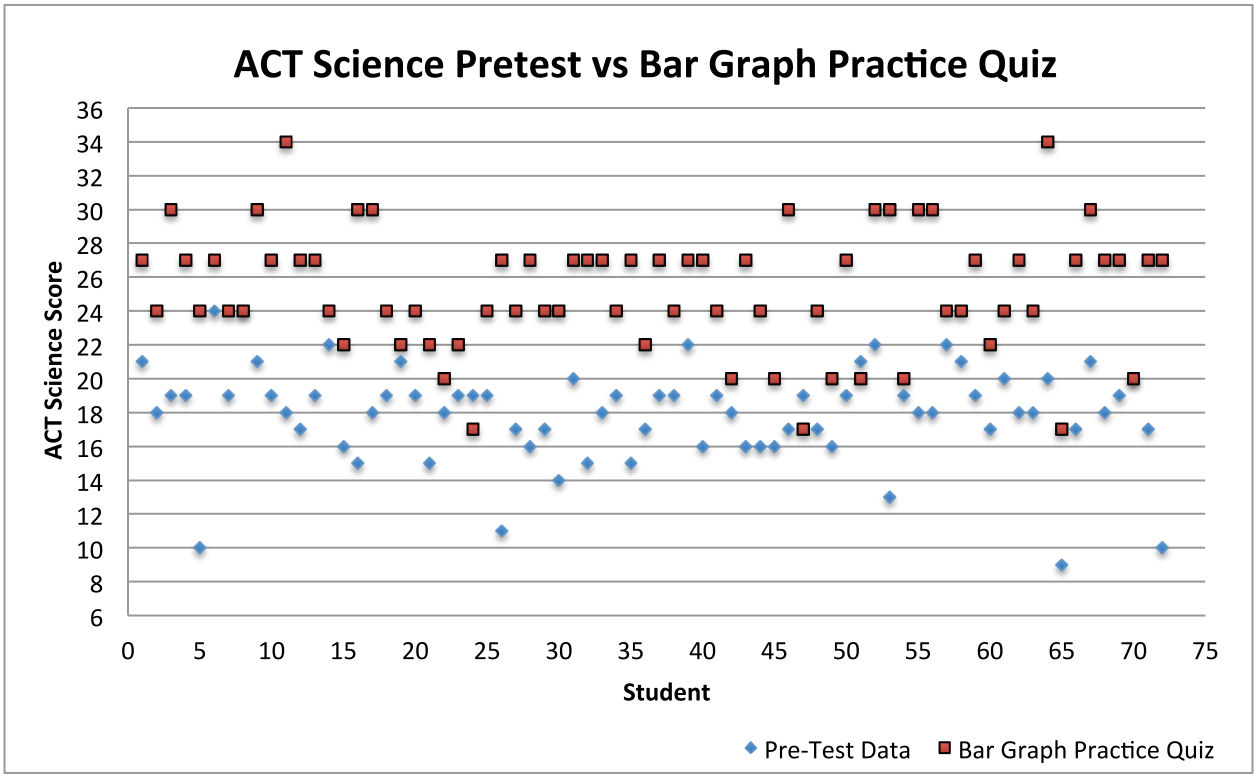

Figure 3 shows that 69 out of 72 students improved from the pre-test to the bar graph practice quiz. Many improved their score by double digits, while some only improved by a couple of points. Not all students improved from the pretest; three students' scores actually decreased (students 24, 47, and 51) while one student's score stayed the same (student 70). As a whole group the average pre-test score was 18.07 while the bar graph practice quiz score was 25.24. This is an increase of 7.17 which is statistically significant according to a t-test ($p= 0.05$).

Figure 4: Grand Ledge ACT Science Pre-test and Single-Line Graph Practice Quiz Results (n=72)

Pre-Test Average= 18.07 Single Line Graph Quiz Average: 21.07

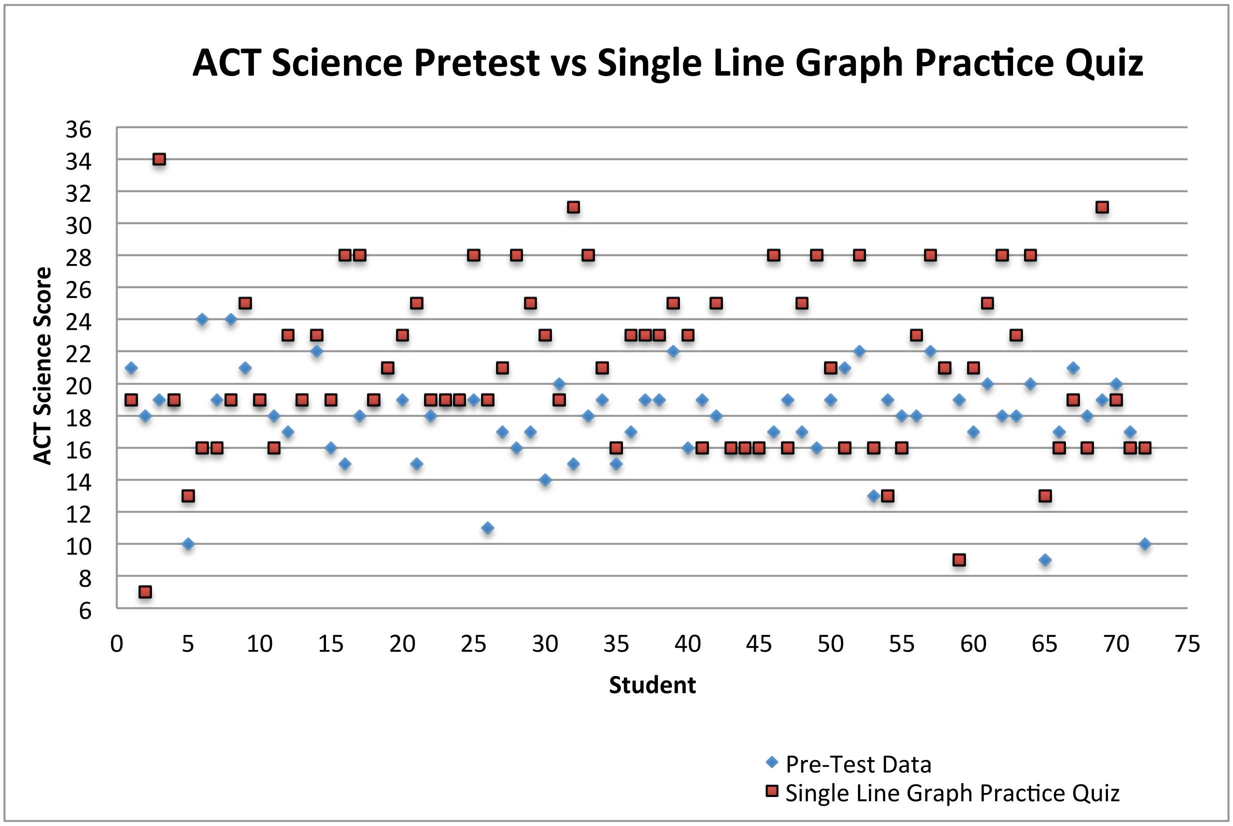

Figure 4 shows that 44 students improved their score from the pre-test to their single line graph quiz. For 17 students, scores decreased, while for 11 students scores stayed exactly the same. As a whole group, the average pre-test score was 18.07 while the single-line graph quiz score was 21.07. This is an increase of 3.0 which is statistically significant according to a t-test (p= 0.05).

Figure 5: Grand Ledge ACT Science Pre-test and Multi-Line Graph Practice Quiz Results (n=72)

Pre-Test Average= 18.07 Multi-Line Graph Quiz Average: 21.04

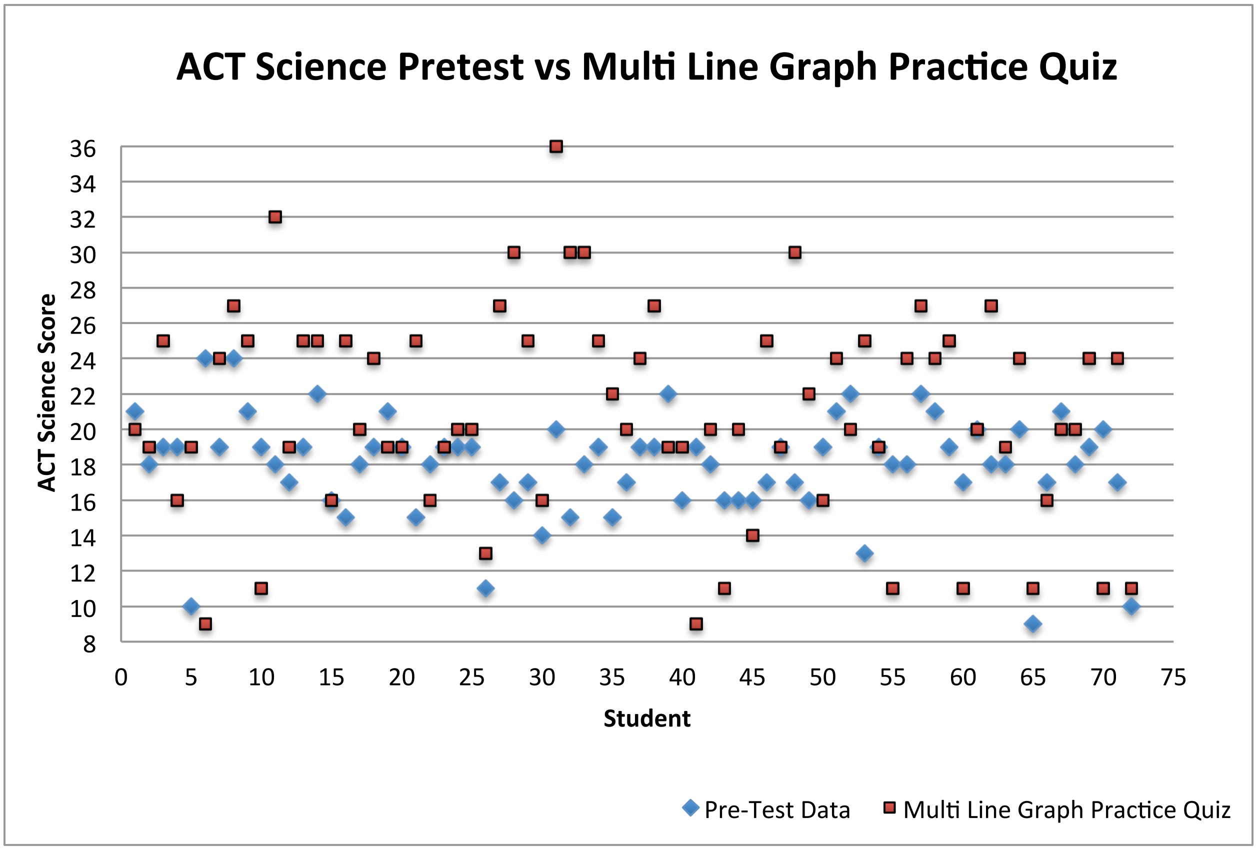

Figure 5 shows that 49 students increased their scores from their pre-test to their multi-line graph quiz. Sixteen student scores decreased and six scores remained the same. As a whole group the average pre-test score was 18.07, while the multi-line graph quiz score was 21.04. This is an increase of 2.97 which is statistically significant according to a t-test (p= 0.05).

In addition to these assessments, individual graphing activities were collected including a pH lab, Pendulum Lab, Bowling Ball Lab, Grow Toy Lab, and Meteorology Lab Graphing Activity (Supplemental Materials B). Every student in this study completed all of the graphing activities mentioned in Table 1. With the constructing table labs (pH lab and student measurement lab) students did not make many, if any, mistakes entering data into their tables. On these labs some students underlined or highlighted main ideas (Supplemental Materials B1 and B2), but few students marked up their tables to find the data attached to follow-up ACT like questions. With the bar graph (pendulum lab) activity no students made any graphing errors. An exemplar example of this lab is shown in Supplemental Materials B3. The bowling ball lab focused on single-line graphing. With this graphing activity students did have a difficult time plotting the data points. This was most likely due to the unique units of the collected data. Students had trouble plotting a point, because they were unsure where to place their data points. Another issue students had while completing this lab was drawing a best-fit line. A lot of the students just connected the dots and did not even attempt to create a best-fit line as shown in Supplemental Materials B4. Supplemental Materials B5 shows an exemplar example of the bowling ball lab. Another interesting point about this lab is that some students who had already taken physics actually wrote down the formula for velocity even though there was no need for math (Supplemental Materials B6). The multi-line graphing activities (grow toy lab and meteorology graphing lab) contained the most student graphing errors. One unusual mistake was made within the grow toy lab. One student graphed the mass, length, and width before and after in a comparison plot (Supplemental Materials B7). This graph should have only included the percentage increase of these measurements. An exemplar student example for this lab presented in Supplemental Materials B8. The last graphing activity (meteorology lab) involved plotting already collected data. The most common mistake on this graphing activity was students connecting data points out of order as seen in Supplemental Materials B9. An exemplar student example for this lab can be found in Supplemental Materials B10.

Table 2 includes a select group of statements collected from the anonymous survey given at the end of the ACT Science rotation. The entire set of survey questions can be found in Appendix D7. The purpose of this survey was to get feedback from students about the activities completed and materials used in the class. The survey's main focus was to question students about what specific activities were helpful and unhelpful to them. It was also conducted to see how students felt about the ACT Science section after their completion of the ACT Science rotation. Almost twenty percent of students felt that the laboratories were not helpful. Only about 7% of the polled students thought the laboratories were beneficial. It is important to note that only the statements that discussed the laboratories or hands-on activities were included in this paper; therefore, only a portion of students responses were included.

Table 2: Student Survey Responses

Student Survey Question	Student Response
What part(s) of this class helped you the most? Why?	- "Labs, paid more attention." - "Labs, b/c it gave a reason." - "Labs b/c they were hands on & that's how I learn." - "The labs because it was fun!" - "Putting the application from the test to labs were helpful because they put a practical and visible thing to go with the questions."
What part(s) of this class helped you the least? Why?	- "The labs because we don't have to make a table on the ACT, Plus I already know how to answer questions based on a table." - "Labs, I already knew how to make tables and graphs." - "I would think maybe the labs because we don't have to fill in info on the ACT." - "The labs because we didn't really use them for the ACT because we already were given all of the info we needed to solve it." - "Doing the labs helped me the least b/c it would have been just as effective with given information." - "The labs. I won't be doing labs on the ACT or collecting data so I would rather spend my time doing beneficial things." - "Labs, open book test don't need to do lab." - "Labs, they didn't help me prepare for the ACT. I know it's good to know how to create the questions." - "When we did labs and drew graphs because drawing those are not on the ACT." - "The labs. They were fun but they didn't help with my knowledge of the ACT." - "The labs but it helped me understand the questions." - "The labs. I don't think they're very helpful for the ACT." - "I don't think the labs helped me all that much because they seemed a lot easier than the actual ACT."
If you could change anything about this class what would you change and why?	- "Not forcing students to take it" - "If I could change anything I would change how many practice tests we had (more of them) and no labs, b/c I don't think they helped." - "Less labs" - "I would take our drawing graphs and collecting data and strictly work on practice problems and how to do them like the other rotations." - "I would take out the labs- they seemed pointless." - "There's nothing I would change."

CONCLUSION

Overall the data show that compared to the pretest, on average students improved their ACT score on all of the mini-quizzes and the post-test (Figures 1-5). Comparing the pre-test to the post-test, a paired T-test (p= 0.05) was conducted. Results show that all pre-test data compared to the mini-quiz data and the post-test data are statistically significant, showing that there is a difference between the pre-test and each of the quizzes and post-test.

However, there was a much larger increase in scores between the pre-test and mini-quizzes than between the pre-test and post-test. These results are most likely due to the level of difficulty of the types of questions on each mini-quiz. The first mini-quiz focus was tables (Figure 2). This quiz had the largest student growth, probably because tables are easier for students to interpret and understand (Meyer et al. 1997). The second mini-quiz focused on bar graphs. This quiz showed the second highest student growth again this material is usually easier for student to approach in a timed situation (Figure 3). The third and fourth mini-quizzes had approximately a three-point increase of student growth (Figure 4 and 5). This growth is much lower than the student growth for the tables and bar graph mini-quizzes, which may be attributed to the level of difficulty of the material. Generally, speaking line graphs are more challenging for students because they require deeper level thinking. This is because students must look at the graph as a whole to gain meaning of the relationships between the variables requiring well-developed problem solving skills (Leinhardt et al. 1990).

Another factor that may have influenced scores is the length of assessment. Each of the mini-quizzes was only a portion of the actual ACT Science test. The first three mini-quizzes consisted of two passages each. The ACT science test appropriates students only five minutes to complete a passage. Therefore, these three mini-quizzes were only ten minutes in duration. The forth mini-quiz consisted of three passages and was fifteen minutes in duration. The post-test was a full-length ACT Science test, which includes seven passages and lasts for 35 minutes. Since the post-test is longer than the mini-quizzes test fatigue may have impacted these results. Students may have had a harder time focusing for a longer period of time. Also the post-test included all types of graphics including tables, bar graphs, single-line graphs and multi-line graphs. Some students might have weaknesses in one or more of these areas that did not affect the individual mini-quizzes.

Finally, one last factor that influenced student success was motivation. Some students were not motivated to improve their ACT scores. One reason students may have lacked motivation was their post-high school plan. Students in this course that are not planning on attending college saw little value or worth in an ACT Score so they did not try as hard as those planning to. Another reason for lack of motivation was the involuntary enrollment in this course. A handful of students were upset or annoyed that they could not take an elective class because they had to take the ACT Skills class. Due to this lack of motivation, some students did not utilize their class time well. In fact, some students completed the mini-quizzes and post-test well before time was called. This lack of effort would have impacted the student growth averages.

Despite the significant improvement on the ACT Science post-test, many students did not attribute that to the hands-on inquiry labs. In fact, the majority of students thought the labs did not help them in any way. Some students described the uselessness of the labs because they already knew how to collect data and create graphs. The majority of students that thought the labs were not helpful explained that it was because they did not have to do it on the actual ACT test. Students had a hard time determining the importance of the hands-on labs. As a result of this in the future I would be more explicit in explaining why we are doing hands-on activities to students. Despite the unpopularity of the labs among the students, some students did express their interest in the labs. The students that did enjoy their labs had a variety of reasons including: helped with attention span, the labs provided an application of the ACT questions, the labs were fun, and they were hands-on. When labs were conducted students seemed more engaged and student participation was increased. In addition, students asked more questions about the relationships between the measured variables, which promoted deeper understanding.

Looking at all of the data together there is a strong indication that student success on the ACT Science section was impacted by the hands-on graphing activities and the other practice that took place. This is most likely because when students actively engage in hands-on science it increases their understanding of the science and it helps them process information more successfully (Patke 2013). It seemed that the activities were effective in meeting both of my goals: improving ACT science scores and increasing student graphicacy. Students not only improved their ACT science scores, but they got better at each graphing activity throughout the science rotation. These gains were a direct result from the hands-on activities, which increased student knowledge and strengthened their ability to apply concepts to new data sets and graphics (Powell 2010). Student graphicacy can only improve from direct data collection and construction, because this engages students and promotes high-level thinking (Leinhardt et al. 1990).

Due to the significant growth of student ACT Science scores I would repeat these activities in an ACT Skill class in the future. However, there are a few areas I would reconsider addressing. First, I would be more intentional when discussing the purpose of the hands on activities to my students. Second, the pace of the course seemed very fast and rushed at the end of the science rotation. In the future, it may be worthwhile to decrease the number of assessments given during the class period. For example, giving a second pre-test during class does not seem as beneficial as using that class period for content. Finally, I would like to increase student involvement in planning and running the different trials in each lab that we do. I think that increasing student involvement in the process of science would increase their scores even further.

Even with the success of this ACT Skill course, unfortunately, this course will not be taught again at Grand Ledge High School. This is because the State of Michigan has chosen to replace the ACT with the SAT. The SAT will be completely revamped and will look brand new starting in September of 2015. The newly refurbished SAT should be similar in appearance to the ACT, but it will not contain a science portion. The science questions will be embedded into the reading and math sections of the SAT. This will change how general test taking strategies would be taught in the science rotation. Due to the implementation of a new SAT test further research is necessary to determine if similar hands-on graphing activities would also positively impact SAT scores.

APPENDIX

Parental Consent and Student Assent Form

Dear Students and Parents/Guardians

I would like to take this opportunity to welcome you to my classroom and invite your son or daughter to participate in a research project. **Utilizing scientific graphing and a laboratory based approach to improve Science ACT scores in High School Students**, which I will conduct as part of ACT preparation course this trimester. My name is Michelle Hamilton and I am your student's ACT preparation course teacher for the first trimester and I am also a master's degree student at Michigan State University. Researchers are required to provide a consent form like this to inform you about the study, to convey that participation is voluntary, to explain the risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

What is the purpose of this research? I have been working on how to better teach the scientific method to high school learners and I plan to study the results of this teaching approach on student comprehension and retention of the material. The results of this research will contribute to teacher's understanding about the best way to teach about science topics. Completion of this research project will also help me to earn my master's degree in Michigan State University's College of Natural Science.

What will students do? Students will participate in the usual instructional curriculum for the ACT preparation course but with added guided and open ended graphing and chart reading activities throughout the first trimester. Students will complete the usual assignments, class demonstrations, pretests, posttests, laboratory experiments, and activities as they would for any other unit of instruction. There are no unique research activities and participation would not increase or decrease the amount of work that students normally do. I will simply make copies of student's work for research purposes. This project will take place in the fall of 2014 and continue throughout the first trimester of ACT preparation. I am asking for permission from both students and parents/guardians (one parent/guardian is sufficient) to use copies of student work for my research purposes.

What are the potential benefits? My reason for doing this research is to learn more about improving the quality of science instruction. I will not know about the effectiveness of my teaching methods until I analyze my research results. If the results are positive, I can apply the same teaching methods to other science topics taught in this course, and ACT preparation students will benefit by better learning and remembering the course content. I will report the results in my master's thesis so that other teachers and their students can also benefit from my research.

What are the potential risks? There are no foreseeable risks associated with completing course assignments, class demonstrations, pretests, posttests, laboratory experiments, and activities. In fact, completing coursework will be very beneficial to students. The consent forms were held anonymously in locked file cabinet that will not be opened until after I have assigned grades for this trimester. That way I will not know who agrees to participate in the research until after grades are issued. In the meantime, I will save all of the written work. Later I will analyze the written work for students who have agreed to participate in the study and whose parents/guardians have consented.

How will privacy and confidentiality be protected? Information about you will be protected to the maximum extent allowed by law. Student's names will not be reported in my master's thesis or in any other dissemination of the results of this research. Instead, the data will consist of class averages and samples of student work that will not include names. After I analyze the data to determine class averages and choose samples of student work for presentation in the thesis, I will destroy the copies of student's original assignments, tests, etc. The only people who will have access to the data are the thesis committee at MSU, the Institutional Review Board at MSU and me. The data will be stored on password protected computers and in locked file cabinets in locked offices on MSU campus for at least three years after the study.

What are your rights to participate, say no, or withdraw? Participation in this research is completely voluntary. You have the right to say "no". You may change your mind at any time and withdraw. If either the student or parent/guardian requests to withdraw, the student's information will not be used in this study. There are no penalties for saying "no" or choosing to withdraw.

Who can you contact with questions and concerns? If you have concerns or questions about this study, please don't hesitate to contact:

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If you have questions or concerns regarding your role as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if desired, MSU Human Research Protection Program at **irb@msu.edu**

How should I submit this consent form? Please complete the attached form. **Both** the student and parent/guardian must sign the form. The ACT preparation student will return the form indicating interest either way.

Please return this form in the provided envelope sealed to the anonymous drop box in Ms. Hamilton's room, 416, by Monday September 22nd, 2014.

Parents/guardians should complete this following consent information:

I voluntarily agree to have ____ participate in this study.

(Student Name)

Please check all that apply:

Data:

______ I give Michelle Hamilton permission to use data generated from my child's work in class for her thesis project. All data shall remain confidential.

______ I do not wish to have my child's work in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of their participation in this research.

Photography, audio recordings, or videotaping:

______ I give Michelle Hamilton permission to use photos, or videotapes of my child in the classroom doing work related to this thesis project. I understand that my child will not be identified.

______ I do not wish to have my child's images used at any time during this thesis project.

Signatures: ____ ___________________

(Parent Signature) **(Date)**

____ ___________________

(Student Signature) **(Date)**

Important

Please return this form in the sealed envelope to the anonymous drop box in Ms. Hamilton's room by Monday September 22th, 2014.

REFERENCES

REFERENCES

ACT. ACT Inc., 2015. Web. 2 Feb. 2015. <http://www.act.org/>.

ACT Inc. "Mathematics Guide to EXPLORE, PLAN, and the ACT Assessment." *Linking Assessment to Instruction in Your Classroom*. Iowa City: ACT Inc., 1996. Web. 26 June 2014.

Allensworth, Elaine, Macarena Correa, and Steve Ponisciak. "From High School to the Future: ACT Preparation-Too Much, Too Late. Why ACT scores Are Low in Chicago and What It Means for Schools." *Consortium on Chicago School Research*. CCSR, May 2008. Web. 26 June 2014.

Aoyama, Kazuhiro. "Investigating Hierarchy of Students' Interpretations of Graphs." *International Electronic Journal of Mathematics Education* 2.3 (2007): 298-318. Web. 14 July 2014.

Bangert-Drowns, Robert L., James A. Kulik, and Chen-Lin C. Kulik. "Synthesis of Research on the Effects of Coaching for Aptitude and Admissions Tests." *Educational Leadership* 41.5 (1983-1984): 80-82. Web. 2 Feb. 2015.

Berg, Craig A., and Philip Smith. "Assessing Students' Abilities to Construct and Interpret Line Graphs: Disparities between Multiple-Choice and Free Response Instruments." *Science Education* 78.6 (1994): 527-54. Web. 25 June 2014.

Bestgen, Barbara J. "Making and Interpreting Graphs and Tables: Results and Implications from National Assessment." *Arithmetic Teacher* 28.4 (1980): 26-29. Web. 3 Mar. 2015.

Din, Feng S., and Christina Soldan, *The Effects of Practice Reading of ACT Science Passages*. Diss. University of St. Francis, 2001. Print.

Fallows, James. "The Tests and the "Brightest": How Fair Are the College Boards?" *The Atlantic Online* 245.2 (1980): 37-48. Web. 3 Mar. 2015.

Friel, Susan N., and George W. Bright. "Building a Theory of Graphicacy: How Do Students Read Graphs?." American Educational Research Association. New York. 8-12 Apr. 1996. Web. 19 July 2014.

Friel, Susan N., Frances R. Curico, and George W. Bright. "Making Sense of Graphs: Critical Factors Influencing Comprehension and Instructional Implications." *Journal for Research in Mathematics Education* 32.2 (2001): 124-58. Web. 25 June 2014.

Higgins, Lori, Kristi Tanner, and Ann Zaniewski. "High school students show improvement, but college-readiness rate drops." *Detroit Free Press* 16 July 2014. Web. 2 Feb. 2015.

Leinhardt, Gaea, Orit Zaslavsky, and Mary Kay Stein. "Functions, Graphs, and Graphing: Tasks, Learning, and Teaching." *Review of Educational Research* 60.1 (1990): 1-64. Web. 2 July 2014.

McBride, Samantha. *Practice Makes Perfect! Teaching Graphing and Using Content Related Graphs in the Biology Classroom*. Diss. U of California Davis, 2009. Ann Arbor: ProQuest LLC, 2009. *ProQuest Dissertations and Theses*. Web. 07 July 2014.

McKenzie, Danny L., and Michael J. Padilla. "The Construction and Validation of the Test of Graphing in Science (TOGS)." *Journal of Research In Science Teaching* 23.7 (1986): 571-79. Web. 11 July 2014.

Meyer, Joachim, David Shinar, and David Leiser. "Multiple Factors that Determine Performance with Tables and Graphs." *Human Factors and Ergonomics Society* 39.2 (1997): 268-86. Web. 15 July 2014.

Michigan Department of Education. *MI School Data*. State of Michigan, 2001-2015. Web. 21 Feb. 2015. <https://www.mischooldata.org/>.

Morgenstern, Carol F., and John W. Renner. "Measuring Thinking with Standardized Science Tests." *Journal of Research In Science Teaching* 21.6 (1984): 639-48. Web. 26 June 2014.

Patke, Usha. *Inquiry-Based Laboratory Investigations and Student Performance on Standardized Tests in Biological Science*. Diss. Walden U, 2013. Ann Arbor: ProQuest LLC, 2013. Print.

Powell, Phillip E. *The Effect of Instructional Methodology on High School Students Natural Science Standardized Tests Scores*. Diss. Walden U, 2010. Ann Arbor: ProQuest LLC, 2010. Print.

Scholes, Roberta, and Margaret M. Lain. "The Effects of Test Preparation Activities on ACT Assessment Scores." American Educational Research Association. Chicago. 24-28 Mar. 1997. Web. 14 July 2014.

Slack, Warner V., and Douglas Porter. "The Scholastic Aptitude Test: A Critical Appraisal." *Harvard Educational Review* 50.3 (1980): 382-401. Web. 2 Feb. 2015.

Stockwell, S. E., Lowenstein, Jeffrey. Schaeffer, Robert. *The SAT Coaching Cover-up: How Test Preparation Programs Can Raise Scores By 100 Points Or More And Why The College Board And ETS Deny The Evidence*. Cambridge, MA. : The Center, 1991. Print.

Tairab, Hassan H., and Ali K. Khalaf Al-Naqbi. "How do secondary school science students interpret and construct scientific graphs?" *Biological Education* 38.3 (2010): 127-32. Web. 25 June 2014.

Tretter, Thomas R., and Gail M. Jones. "Relationships Between Inquiry-Based Teaching and Physical Science Standardized Test Scores." *School Science and Mathematics* 103.7 (2003): 345-50. Web. 2 July 2014.

Turner, Matthew J., and Jose M. Rios. "Determining Paths to Success: Preparing Students for Experimental Design Questions on Standardized Tests." *The American Biology Teacher* 70.3 (2008): 140-52. Web. 2 July 2014.

Wolff, Michael R., and Michelle K. McGinn. "Graphing: Cognitive Ability or Practice?" *Science Education* 81.1 (1997): 91-106. Web. 28 June 2014.

Yeh, Yi-Fen Y., and Erin M. McTigue. "The Frequency, Variation, and Function of Graphical Representations within Standardized State Science Tests." *School Science and Mathematics* 109.8 (2009): 435-49. Web. 3 July 2014.