THE EFFECTS OF GRAPHING SOFTWARE ON STUDENTS
ABILITY TO ANALYZE DATA

by

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ABSTRACT

In order to think critically in today’s world, the Partnership for 21st Century Learning states that students will need to be able to analyze data. Also, a large portion of standardized testing is reading and interpreting graphs. These two factors determined the goal of this project. The goal of this project was to determine the effectiveness of TinkerPlots software on student’s ability to analyze data. This paper covers seven months of the project where the students were taught how to use the software and then used it on multiple projects. Data collected indicates that the students’ ability to analyze data increased and their attitudes improved when analyzing data. Data also indicated that teacher’s attitudes improved when teaching data analysis.
INTRODUCTION AND BACKGROUND

I am concerned about students’ ability to read and interpret graphs. It started two
years ago when I was waiting for my son to complete his high school placement test. A
student of mine walked by and said, “Mr. O’Leary, the science test is all graphs.” That
placement test was early spring 2012. In the fall, we give our students the Iowa Test of
Basic Skills. The test was recently updated to meet current standards. Our students’
scores were lower on the new version. In the fall of 2012, I took a long look at the test.
About 50% of the science questions involved looking at graphs or tables and answering
questions.

These two events caused me to worry about my students’ abilities to analyze data
and to increase my efforts in this area. Two years ago, I increased the role of graph
creation and graph interpretation in the curriculum. When I started this project, it was still
paper and pencil. This created two questions: was this enough, and was it working? I had
anecdotal evidence that students’ abilities were improving, but nothing quantitative. I
wanted to do this action research to collect quantitative and qualitative evidence about
students’ abilities to analyze data while using graphing software.

I am convinced that graphing software will allow students to create graphs faster
and with more variety. The ability to do this will increase student’s understanding of how
different graphs tell different stories about the same data. Being able to quickly create
various graphs will also allow students to analyze the data in different ways which should
lead to more ideas and interpretations. Using graphing software will also allow students
to ask more “what if” questions by quickly changing, adding, or deleting data. I believe
graphing software will improve student’s information literacy, statistical literacy, and
data literacy skills better and faster than traditional pencil and paper methods (Chance, Ben-Zvi, Garfield, and Medina, 2007).

If this action research (AR) is successful, the treatment will be useful in many areas. The ability to analyze data is useful in many subjects in school. Students analyze data in science, math, social studies, and even occasionally in language arts. This action research is focused on middle school, but students as young as fourth grade could use the software. This study might be useful to other schools as well since all schools work to improve students’ ability to analyze data.

Based on my concerns about my students’ ability to analyze data for standardized testing and the need for this skill in many subject areas, I developed the following AR questions:

AR question:

1. What effect does graphing software have on student’s ability to analyze data?

Sub questions:

2. What effect does graphing software have on student’s attitudes when analyzing data?

3. What effect does graphing software have on teacher’s attitudes about teaching data analysis?

I teach middle school science at Sacred Heart School. It is a private Catholic School located in St. Louis County, MO. St. Louis County is divided into 91 municipalities and unincorporated area. It covers 524 square miles, and in 2010, had a population of 998,954 (St. Louis County). Sacred Heart School has 310 students in
grades pre-school through 8th grade and is located in the town of Valley Park. There are one or two classes per grade. Sacred Heart School draws students from within parish boundaries. Within the boundaries are all or parts of the cities of Valley Park, Twin Oaks, Fenton, and unincorporated area. Fenton is the largest of the three.

According to the Fenton city website, there are 45,590 people living in a three mile radius of Fenton. This three mile radius includes most of the Sacred Heart School area. Table 1 shows some demographics of this three mile radius.

Table 1  
**Demographic Data of Population in Sacred Heart Parish Boundaries**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>46,317</td>
</tr>
<tr>
<td>Median Age</td>
<td>40.00</td>
</tr>
<tr>
<td>Households</td>
<td>18,343</td>
</tr>
<tr>
<td>Average Household Size</td>
<td>2.49</td>
</tr>
<tr>
<td>Average Household Income</td>
<td>$78,860</td>
</tr>
<tr>
<td>Median Household Value</td>
<td>$222,847</td>
</tr>
</tbody>
</table>

As of the census of 2010, the racial makeup of the city of Fenton was 95.5% White, 0.4% African American, 0.2% Native American, 2.1% Asian, 0.2% Pacific Islander, 0.3% from other races, and 1.3% from two or more races. Hispanic or Latino of any race was 1.9% of the population.

In summary, the school and community are relatively old, but the area has undergone rapid growth over the last 20 years. This accounts for the young age of the
population. The area is fairly affluent and not very diverse. This mirrors our school community.

This AR project was conducted with the entire seventh grade, which has a total of 33 students. There were two classes of students. There were 16 students in the class designated 7H, and there were 17 students in the class designated 7R. Overall, there were 14 girls and 19 boys. 7H had nine boys and seven girls; 7R had 10 boys and seven girls. There were no English Language Learners in this class and 31 students were Caucasian. Four students have Individualized Education Plans, and I would qualify their motivation as average during my five years of experience. 7H is quieter than 7R.

Students have very little exposure to graphs and data analysis prior to sixth grade. I chose the seventh grade because I felt they had the right balance of experience with graphs. The sixth grade is too new and still trying to get used to middle school. Eighth has the most experience and training with graphs. I wanted a group with enough exposure to not be afraid and not too much exposure to see how much they could grow.

I had a great team assist me on this project. The first person on the team was Kathy Ebert. She is an excellent middle school math teacher. She is an excellent teacher, a calming influence, and a source of wisdom. She helped me choose, plan, and execute the treatment.

The second person on the team was Katie Hoover. She has a science background and is the middle school language arts teacher. She was a critical friend who edited this capstone paper and made it better.
My third team member was Linda Pendleton, the school computer teacher. She helped me select the software. She was invaluable helping me teach the software to the students. She is also a person who is amazing at helping out in those unexpected ways.

My reader was Mr. Joseph Bradshaw. I took his Plant Science course and found his optimism and enthusiasm infectious. My project advisor was Dr. Walter Woolbaugh. I can’t thank him enough for his support and encouragement.

CONCEPTUAL FRAMEWORK

As a science teacher, I want to prepare students for their future beyond just science content. They need to develop critical thinking skills. Analyzing data is a critical thinking skill that can be taught in a science classroom. Software is valuable in teaching this skill.

William Garrison (2008) wrote, “The primary mission of schooling should not be to prepare for the next grade level but to help students understand, to make sense of, and to be successful in their world today and tomorrow” (p. 348). I considered this comment so profound that I posted it in my classroom on my first day of teaching. I can’t think of a better mission statement.

However, achieving the mission is more challenging than posting it on the wall. First, the goals of this mission statement needed to be defined. I struggled with turning the goals into something concrete. I knew I had to teach content that would allow students to make sense of and understand the world, but, as a science teacher, I knew that most students wouldn’t be science professionals. How could I help them be successful regardless of what they chose to do in life?
Terms like critical thinking, communicating, and collaborating kept bouncing around in my head. Improving these skills would make great goals, but what exactly do those terms mean? How do I teach those skills? During the last several years, I found many different definitions for these terms. I knew that I needed to settle on definitions and goals. The research for this project led me to the Partnership for the 21st Century Skills.

The Partnership for 21st Century Skills (2014) states that students need to have information skills that include accessing, evaluating, managing, and using information. In order to be good critical thinkers students need to:

*Reason Effectively*
- Use various types of reasoning (inductive, deductive, etc.) as appropriate to the situation

*Use Systems Thinking*
- Analyze how parts of a whole interact with each other to produce overall outcomes in complex systems

*Make Judgments and Decisions*
- Effectively analyze and evaluate evidence, arguments, claims and beliefs
- Analyze and evaluate major alternative points of view
- Synthesize and make connections between information and arguments
- Interpret information and draw conclusions based on the best analysis
- Reflect critically on learning experiences and processes
Today, people have near instant access to massive amounts of information due to the internet. Students have the tools to access this information, but do they have the skills to evaluate and analyze this information (Gunter, 2007)? In order to think critically in today’s world, students will need the skills of information literacy, statistical literacy, and data literacy (Shields, 2007). Informational literacy requires students to read, interpret, and evaluate information, while statistical literacy involves analyzing, interpreting, and evaluating statistics. Students will also need to access, manipulate, and summarize data which are the components of data literacy.

We are in the 21st century. Students will need to learn critical thinking skills and informational skills to be successful in the world, both today and tomorrow. I settled on definitions of the terms and skills that students will need. Improving student’s ability to analyze data will improve statistical literacy, data literacy and the critical thinking skills of reasoning effectively and making judgments.

Statistics education is a relatively new and emerging discipline (Garfield and Ben-Zvi, 2007). The first journal, *Statistics Education Research Journal* was established in 2002. Prior to 2009, Watson and Donne (2009) write, “There appears to have been no research, however, comparing software and non-software setting for exploring students’ statistical understanding in a more general sense, not associated with a particular classroom intervention” (p. 1). While the depth of the research in this field is not as great as other fields, the good news is that it is all recent, and I am involved in something new.

Statistics is a challenging subject for many. Garfield and Ben-Zvi (2007) write, “The studies suggested that the concept of the average is quite difficult to understand by
children, college students, and even elementary school pre-service and in-service teachers” (p. 19). They also found that students and adults have many misconceptions that good instruction doesn’t always overcome. The authors go on to suggest that well designed lessons using technology, active student involvement, and students confronting misconceptions can help students understand statistics.

Garfield and Ben-Zvi (2007) write, “Statistical literacy is a key ability expected of citizens in information-laden societies, and is often touted as an expected outcome of schooling and as a necessary component of adults’ numeracy and literacy” (p. 15). Statistical literacy is the understanding and use of the basic terms of statistics. Statistical reasoning is the ability to make sense of the results while statistical thinking is the understanding of statistics theory reserved for professional statisticians.

Students tend to see data sets as individual points and not as a whole (Garfield and Ben-Zvi, 2007). I think moving the students from seeing data as individual points to a collective whole will be one way of moving the students from statistical literacy to statistical reasoning. Garfield and Ben-Zvi (2007) also suggest that to move students to statistical reasoning, they need to be given multiple opportunities to analyze the same data, find patterns in the data, and to notice the unexpected. The goal of my study is to improve student’s statistical reasoning, but I will first have to improve student’s statistical literacy.

In 1995, one of the authors, Joan Garfield proposed 10 principles for teaching statistics. In this article, Garfield and Ben-Zvi (2007), revise the 10 principles into eight research-supported principles. One of these principles is to use technological tools to help
visualize and explore data. Therefore, I chose to use software for my technology tool in this study.

Graphing software is good for teaching students statistics and also has an advantage over pen and paper. Graphing software can easily include the many data repositories that are on-line. The Data and Story Library (http://lib.stat.cmu.edu/DASL/) and the Journal of Statistics Education Dataset (http://www.amstat.org/publications/jse/jse_data_archive.htm) are two examples. These data sets come with stories and classroom activities. While authentic student data is important, using data for problem based learning activities could be just as important. The use of graphing software allows for easy incorporation of these data sets along with any real world problem data sets that a teacher may want to use. While I did not use data sets in this AR, I will use them in the future because they can save time and give students access to data they might not be able to collect on their own.

One characteristic of using graphing software I did not realize is its support for constructivist teaching. Software has been designed for students to build their knowledge of statistics in their own way and at their own pace. Some programs allow students to explore on their own, and the need for teacher support reduced along the way (Chance et al., 2007).

The authors make two more suggestions for teaching with graphing software. First, when using software to teach graphing, remember to keep the experience student-centered versus drill and practice. Second, don’t let the graph be the only result. Students
will gain the most knowledge by explaining, justifying, and communicating their conclusions about the graph.

“Technology should not be used merely for the sake of using technology,” state Chance, Ben-Zvi, Garfield, and Medina (2007, p 2). Instead, when choosing statistical software, pick software that will require students to think versus simply using trial and error. The authors reviewed three software packages: TinkerPlots, Fathom, and InspireData. All three were given good reviews, and the authors note that the latter two are designed for students in grades 4-8. The authors also recommend not using Excel or graphing calculators to teach students graphing skills. Neither is specifically designed for teaching those skills. In addition, calculators are not very good for communicating results. While Excel was not the main component of my treatment, I still used it because after exploring the different software, I decided that it is the best for making graphs to display.

I chose to use TinkerPlots for this project because of four reasons. First, it was made for middle school students. Second, it was modeled after video games. Third, research has been done with this software. Fourth, it was free.

The software TinkerPlots was developed for middle school students to help them visualize data and understand statistics (Konold, 2007). Asking what statistical skills citizens need today and what they will need 25 years from now drove the designers. Konold (2007) writes, “The objective has become not to teach statistics to a few but to build a data literate citizenry” (p. 268).
In creating the software, the designers thought about the three ways to design instruction. First, there is the top down method where the ultimate goals of college-level standards are thinned as you go down through the grades. The second method is the bottom-up. This method takes into account the goal for students and where they are coming from. The designers of TinkerPlots used a third method. They assumed they did not know where K-12 standards where headed and there were many ways students could learn.

The designers felt the third method should yield a tool that gains complexity as students gain understanding at their own pace. The students would start at the beginning and have very little limit to where they could end up. This is in contrast to a step by step curriculum where, for example, students all learn linear graphs in grades five and six and then learn scatterplots in grades seven and eight.

A tool that would gain complexity as students gain understanding, would meet the students where they are at, and be very familiar to them. Console games like Xbox use this approach, and most students are familiar with console games. The designers also made TinkerPlots like a construction set of blocks. Randomly pressing buttons, like randomly stacking blocks, would yield poor results. Students have to make thoughtful decisions to produce a clear representation. This leads to students taking ownership of their learning.

A study by Watson and Donne (2009) focused on using TinkerPlots to check student understanding of statistics. This study compared students who used TinkerPlots for two protocols versus students in previous studies who used pen and paper on the same
protocols. The three groups are labeled A, B, and C. The A group consisted of 88 students in grades three through nine. Group B, consisted of 27 grade 5/6 students. Both of these groups used paper and pencil. The C group used TinkerPlots and was made up of 12 grade 5/6 students and 12 grade seven students. All students were Australian.

The first protocol was comparing four sets of data. Each set contained two groups of data. The data represented student spelling scores by class. The students had to compare the two groups in each set and identify which class did better in spelling. The sets of graphs got progressively harder.

The paper and pen groups were given the data in the form of bar graphs. The TinkerPlots group was given the data in the form of numbers which they had to do something with. Both the TinkerPlots group and the pen and paper groups completed this successfully. However, the difference was that the TinkerPlots group used multiple methods to answer the question.

The second protocol involved sixteen data cards. Each card represented a student. The cards contained a variety of information like name, eye color, favorite activity, etc. Students were asked to look at the data, make hypotheses, and defend them. The main differences between the paper and pencil groups and the C group were that the TinkerPlots group explored more graphs and plots and did it quicker than the pen and paper groups.

In summary, the authors feel that the three main advantages in using TinkerPlots to explore student understanding of statistics is flexibility of representation, speed of analysis, and exposing levels of understanding. The authors have one more important
point that is not covered by this study. When students use TinkerPlots, they create many different graphs. It would be a great learning experience for the students to share and explain their graphs.

There was a study by Fitzallen and Watson (2010) that was based on 26 Year 5/6 students in Australia. These students were between 10 and 12 years old. The students had no previous statistical experience. They were taught four lessons that introduced TinkerPlots by comparing two data sets. During the lessons, seven out of eight elements of Pfannkuch’s Beginning Inference Framework (Pfannkuch, 2006) were repeatedly covered.

The students did not use TinkerPlots for the following month. Twelve students were then selected, based on parental permission and conversational ability, to do a follow up exercise. The exercise was based on one previously used with TinkerPlots (Watson & Donne, 2009). The exercise consisted of three scenarios where the students used TinkerPlots to compare data.

The authors used Pfannkuch’s model as a basis for a protocol to measure students understanding of statistics. Elements of Pfannkuch’s model were incorporated into a rubric giving a score of one through three, where three is the highest, in each of the three scenarios as well as an overall score. The score was based on interviews and saved TinkerPlots files. One student did not save files, therefore was given a score of one in all categories. Of the remaining 11 students’ overall scores, four scored a three, five scored a two, and two scored a one. In summary, TinkerPlots was part of an intervention that helped students to compare data, interpret data, and support a conclusion about data.
One of the goals of graphing data is to make sense of or be able to tell a story about the data. To achieve this goal, TinkerPlots features a tool called a hat plot. It looks like a hat where the crown is a rectangle and the brim is a line. The brim shows the range of the data set and in default mode the crown shows the middle 50 percent of the data. The hat plot can be superimposed over the individual data points. A hat plot is comparable to the more familiar box and whisker (Watson, Fitzallen, Wilson, & Creed, 2008).

Watson, et al. (2008) studied 15 students in grades five to seven who analyzed class height data for students in grades five to eight. They found that in addition to being interested in the individual data points, the hat plots helped the students see the group characteristics of the data set. The ability to look at group characteristics improved the student’s ability to tell a story about the data.

I find it interesting seeing how the research in statistical education has changed. It has evolved from looking at how students learn statistics and the issues they face learning statistics to using computers to help teach statistics to constructivist software development and the emergence of the importance of data and statistical literacy. I knew my subject was important to me; now I am convinced that it is important for my students and their development of 21st century skills.

**METHODOLOGY**

**Project Treatment**

I used TinkerPlots (Konold and Miller, 2005) as the core part of treatment. TinkerPlots is very useful to manipulate and model data sets, especially multivariate data.
It is not very useful if you want to make a simple bar graph, print it, and post it with a lab report or project on whiteboard when giving a presentation. This is one reason I also used Excel in the treatment. Excel is good at making report ready graphs. The other reason is that Sacred Heart is moving to cloud based computing and students will be able to use Excel at school and home.

Students do not have laptops, and my classroom has two computers. We have a computer lab with 35 computers. The middle school is only allowed to use it on Tuesdays and Thursdays, and five teachers vie for the spots so I booked the computer lab for two months.

Treatment began with a training session (Appendix A) on using Excel designed by the computer teacher Linda Pendleton. She led the instruction, and I assisted. This was done in two class periods. They made a pie graph of population density from her instructions and they then practiced making a bar graph and a pie graph using skill sheets (Appendix B) from Scholastic Science World (Science World 2012, 2013).

We introduced TinkerPlots (Konold and Miller, 2005) over two class periods. The first class period the students used the basics tutorial built into the software (Appendix C). In the second class period the students used the data analysis tutorial which was also provided with the software (Appendix D). During the next two class periods, they practiced using the Who Has the Heaviest Backpack activity (Appendix E) (Key Curriculum Press, 2012).

The following week, I had the students weigh their own backpack as they entered school. They used this data to practice with TinkerPlots for two more class periods. The
students were allowed to enter any additional data about students that they wanted to use such as gender and eye color.

The treatment (Watson and Donne, 2009 & Fitzallen and Watson, 2010) discussed above was modified. I only used the Data Card portion (Appendix F). In Data Cards, the students are given 16 sets of data. Each set, or card, represents a person. Each card has a name, age, favorite activity, weight, eye color, and number of fast food meals eaten in a week. The students then have to organize the data, form a hypothesis, and explain. This was used before and after treatment. In addition to being part of the treatment, I also considered it a data collection tool. Students have never had the opportunity to look at multivariate sets of data, so the pre activity was also a learning experience. Pretreatment the students only used pencil and paper to complete the activity. Post treatment the students used TinkerPlots.

**Data Collection**

The outline of my data collection strategy was that prior to treatment I conducted interviews, administered surveys, and assessments. During the treatment I used Minute papers, quick surveys, and interviews to collect data. After the treatment I conducted interviews, administered surveys, and assessments. To increase credibility I used multiple sources of data to answer my AR questions. Since my basic premise was that my treatment will improve student’s confidence and ability to analyze data, these data collection tools worked well. I also understand that this is my main bias, and I used critical friends to review my data to minimize my bias. Table two is my triangulation matrix.
Table 2

*Triangulation Matrix*

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Pre/Post Assessments</th>
<th>Pre Interview</th>
<th>Pre Survey</th>
<th>Minute</th>
<th>Post Survey</th>
<th>Student Interview</th>
<th>Teacher Interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>What effect does graphing software have on student’s ability to analyze data?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>What effect does graphing software have on student’s attitudes when analyzing data?</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>What effect does graphing software have on teacher’s attitudes about teaching data analysis?</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Prior to treatment I conducted interviews, administered two surveys, gave three background knowledge probes to assess knowledge, and did the paper and pencil Data Cards project. Appendix G has my student survey. This survey is mostly addressing my question about student attitude. The survey took longer than expected so I eliminated the questions about content and classes for the post survey (Appendix H). The content questions are covered by the assessments and the classes’ questions do not address any of my research questions. The students put their names on the surveys so that I could compare with post survey results.

I also wanted to investigate teacher attitudes so I created a survey. Appendix I has the teacher survey. I surveyed the math, social studies, and computer science teachers before and after treatment. I modified the post treatment survey (Appendix J) to more accurately collect data on what we did.
In order to answer my primary AR question I developed several assessments. Initially I made two background knowledge probes that probed students’ knowledge of vocabulary, ability to make graphs, and read graphs. Since the students were very successful on these two probes and this AR was not really about vocabulary, I did not use these for post assessment. I also made an assessment to measure student’s ability to read a graph, make predictions, and inferences. After seeing what TinkerPlots can do, this assessment became irrelevant so it was not used for post assessment.

This was a recurring theme throughout the AR. I wish I knew then what I know now. Many of my pretreatment questions on surveys, questions in interviews, and assessments in general were totally inadequate with respect to what this AR became. This was both exhilarating and exhausting. It was exhilarating because of the great results and exhausting because of all the work that was unused. I used a lot of minute papers, quick surveys, and interviews during treatment because of this constantly changing atmosphere.

In addition to the three assessments I used prior to treatment, I used the Data Cards activity. The students were each given a set of 16 Data Cards (Appendix F). Each card has information about a person. The student had to look at the cards, generate a hypothesis, and create a graph that supported the hypothesis. The students could only use paper and pencil to generate the graphs. After treatment I used the same Data Card activity except this time, the students could use TinkerPlots to look at the cards and to generate the graphs.

I also had three unique opportunities to gather post treatment data. The first came during a routine assignment about measuring hand span variation in the class. The
students collected the hand span data and I allowed collecting of any additional data they chose. This included things like height and shoe size and I called it the Hand Class Data activity. Due to fortuitous scheduling conflict, only one class could get into the computer lab. This meant that one class used TinkerPlots and one used paper and pencil. This yielded great comparison data about student ability and attitude.

The second opportunity came when the math teacher had the students complete a product survey project. The project included making a graph to support their survey. I was able to interview the math teacher to gather qualitative ability and attitude data. I also surveyed the students to gain additional data to help answer questions about attitude and ability.

Asking the social studies teacher if she had any graphing activities planned in the near future, gave me the third opportunity. The students were to compare demographic data between at least three countries. They had to look for patterns and generate a research question. The teacher agreed to have the students use TinkerPlots to compare the data and generate graphs. This data helped answer questions about ability and attitude.

The goal of my AR project was to improve student’s ability to analyze data in my class and in all aspects of their lives. With that in mind, the validity types I was most concerned about increasing were transferability, truth-value, neutrality, and consistency. I believe that I have provided a description of the setting so that someone could determine if my results would be transferable and be consistent to his setting. I collected data and the students used TinkerPlots for four months. I believe that this persistent and prolonged
observations increased truth-value validity. I conducted many member checks and use critical friends often to increase neutrality validity.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. The exemption can be found in Appendix K. Appendix L has an overall timeline of treatment and data collection.

DATA AND ANALYSIS

The centerpiece of my AR was the Data Cards project. Before learning how to use TinkerPlots, the students were given the Data Cards as separate pieces of paper. After learning how to use TinkerPlots the students were able to see the Data Cards in TinkerPlots. Like the study conducted by Watson and Donne (2009), the students had to look at the data, make hypothesis, and defend hypothesis. I use the words prove and support as synonyms of defend. Table 3 has a summary of key points comparing the use of paper and pencil with TinkerPlots.
Table 3
Comparing the Seventh Grade Student Results While Using Paper and Pencil Versus TinkerPlots on the Data Cards

<table>
<thead>
<tr>
<th>Category</th>
<th>Paper and Pencil</th>
<th>TinkerPlots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=33</td>
<td>N=33</td>
</tr>
<tr>
<td>Total Number of Hypotheses Made</td>
<td>83</td>
<td>108</td>
</tr>
<tr>
<td>Average Number Hypotheses Made</td>
<td>2.5</td>
<td>3.3</td>
</tr>
<tr>
<td>Number of Unique Hypotheses Made</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Number of Students Who Proved Hypothesis</td>
<td>13</td>
<td>24</td>
</tr>
<tr>
<td>Percent of Group That Proved Hypothesis</td>
<td>39%</td>
<td>73%</td>
</tr>
<tr>
<td>Number of Graphs Made</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>Average Number of Graphs Made</td>
<td>1.4</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The total number of hypotheses generated by the students increased by 30% when using TinkerPlots. The average per student increased from 2.5 to 3.3. The number of unique hypothesis also increased from 12 to 18. This is an increase of 50%. The number of graphs generated by the students increased 44% when using TinkerPlots. The main reasons, I believe, for these increases, are the speed and ability to compare attributes when using TinkerPlots. It is simply easier to use TinkerPlots than paper and pencil. Like Watson and Donne (2009) discovered, both groups can complete this part of the assignment, but the TinkerPlots group can do it faster and in greater variety of methods.

Unlike Watson and Donne (2009), my students were not very successful with completing the defend your hypothesis portion of the activity. Only 39% of the group could prove their hypothesis when using paper and pencil. The good news is that TinkerPlots helped increase that number to 73%. The two reasons the students failed to
support their hypotheses when using TinkerPlots were not using the mean and not making a clear hypothesis. Of the nine students that did not support, five of the students should have incorporated the mean into their graph to defend their hypothesis. The other four that did not defend had unclear hypotheses.

All four with unclear hypotheses struggle with written expression. I don’t think TinkerPlots will help students express their thoughts in writing. Of the five students who should have used the mean, four out of five have a tendency to do the least amount of work to complete an assignment. The fifth student is a hard worker and on this assignment tried to do too much, he generated 5 graphs, but his work lacked focus. In time, I think most of these students could improve. Since TinkerPlots saves time on comparing attributes and generating graphs, they could spend more time on writing and clarifying their thoughts.

I wanted to look more closely at this part of the Data Cards project and trends in the students before and after success in defending their hypothesis. Table 4 summarizes this data.

Table 4
Comparison of Student Success with Defending Hypothesis Between Using Pencil and Paper and TinkerPlots N=33

<table>
<thead>
<tr>
<th>Paper and Pencil</th>
<th>TinkerPlots</th>
<th>Number of Students</th>
<th>Average Semester Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pass</td>
<td>Pass</td>
<td>11</td>
<td>3.7</td>
</tr>
<tr>
<td>Fail</td>
<td>Pass</td>
<td>13</td>
<td>3.3</td>
</tr>
<tr>
<td>Pass</td>
<td>Fail</td>
<td>2</td>
<td>2.4</td>
</tr>
<tr>
<td>Fail</td>
<td>Fail</td>
<td>7</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Seven of the students did not prove their hypothesis with paper and pencil or TinkerPlots. These seven and the two who failed with TinkerPlots are the same group
examined above. Mrs. Ebert, our math teacher, noticed something in common with this group. She said, “They tend to work too fast without reading directions.” Doing the least and not following directions is a detrimental combination that leads to low scores.

Based on semester average, TinkerPlots helped the middle students the most on the Data Cards project. The upper students are successful anyway and the lower still struggle. While it’s disappointing that nine did not pass with TinkerPlots. It is exciting to see that thirteen students improved.

It is also great to hear their enthusiasm. One student said, “I would love to get this program on my computer.” Another student said, “I had a lot of fun trying to find new ways to create an interesting graph/project idea.” TinkerPlots is easy to use and let’s students have some freedom in the way they work which leads to more enthusiastic students and a better learning environment. I think one student expressed how TinkerPlots improves data analysis best. He said, “One thing I did notice was how men favored TV more than anything, which makes me think, who is heavier, the men or the women.” He not only noticed a new hypothesis from looking at his first, he went on to prove it.

While using paper and pencil, all students only proved or attempted to prove one hypothesis. With TinkerPlots, seven students proved two or more hypothesis. One student proved six. This is due to ease of use and speed when using TinkerPlots.

The students generated 50% more unique hypotheses when using TinkerPlots. I believe this is due to the speed in which students can compare attributes. Students are also able to add their own attributes. For example, the cards had number of fast food
meals eaten per week. One student added the attribute of fast food lover and defined it as those who ate more than five per week. These two reasons show that using TinkerPlots allows students to analyze data better.

Another valuable reason for using TinkerPlots, or even Excel, is that student work is much neater. This leads to happier teachers. I do not like grading messy work. It is easier and faster to review and grade neat work.

When analyzing the pre and post student surveys, I looked at the following four questions as a group:

What do you think a graph is?

Why are graphs made?

Do you think graphs are important? Why or Why not?

Why do you think information is often presented in graphs instead of just in a list or table?

As stated earlier, students will need the skills of information literacy and data literacy to be successful so I looked for key words in the student responses to this group of survey question. These key words are both the definitions of the skills and middle school synonyms that show students understanding of what the skills of informational literacy and data literacy mean. These skills were not implicitly taught or discussed. Table 5 below shows the words students used and the skills I matched them with.
Table 5  
*Student Responses Aligned With Skills*

<table>
<thead>
<tr>
<th>Skill</th>
<th>Synonyms (words and phrases)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Informational Literacy: read, interpret, and evaluate information</td>
<td>patterns, trends, compare, contrast, hypothesis, find things, show differences, get a better picture, see info you didn’t see before, prove, connect, sequence, and understand</td>
</tr>
<tr>
<td>Data Literacy: access, manipulate, and summarize data</td>
<td>display, show, sort, find the right data, explain, show differences, see things you didn’t see before, and show info the way you want to present it</td>
</tr>
</tbody>
</table>

Figure 1 shows the average number of key word responses pre and post survey.

The average number of key word responses increased from 2.4 to 4.2 per person. In the pre-survey, there were four students who did not use any keywords and eight students who only used one keyword in their response. In contrast, there were no students who responded without the use of a keyword and only one student who used one key word.

The class progressed from 21 students using two or more keywords to 32 students using two or more words in describing graphs. I believe that this shows a significant growth in understanding the purpose of graphs. Even more significantly, since this was not implicitly taught, the students gained this understanding on their own. I believe this happened because the students took ownership in the process and enjoyed it.

The average number could have been higher. There were six students who decreased the number of words they used in the post survey. In the pre-survey these students had an average word response of 4.4. I did not see any patterns between responses and grades. I even noticed that a student who struggles with vocabulary had 11 key words in his response.
Figure 1. Graph comparing average number of synonyms used to respond to the four questions before treatment and after treatment, \((N=33)\).

In the survey, I asked the students to rate themselves on a scale of 1-10, 10 being very confident and 1 being no confidence, in three areas: ability to make a graph, ability to make the right graph, and the ability to read a graph. I did not let the students see their pre-survey while taking the post survey. I was surprised at the results. Many students rated themselves no change in ability and quite a few rated them lower in ability after treatment. Since the post treatment survey was given approximately five months after the first survey and I did not let them look at their scores on the pre-survey when taking the post survey, I thought the length of time was the problem. To find out, I gave them both surveys to look at and tell me if the relationship between the before and after numbers was accurate and if not, why was it not accurate. The revised results are shown figure 2.
Figure 2. Revised average score comparing confidence on a scale of 1-10, were 10 is very confident and zero is no confidence, before treatment and after treatment on ability to do three graphing skills, (N=33).

Fourteen students did not change their responses. The other nineteen students increased their post survey scores, decreased their pre survey scores, or did both. The two main themes that emerged from students that changed their scores were “arrogance”, as one student answered, and forgetfulness. The student who mentioned arrogance said, “I thought I knew everything about graphs, but I didn’t.” Another student responded, “I forgot what number I put the first time.”

As you can see, there were increases in all three categories. The most significant being the ability to make a graph. I think the increase is greatest in this category due to the fact that most students only used paper and pencil before the treatment. There were only a couple of students who used software to generate graphs in the past. The other two skills increased but not as much as making. In hindsight, these weren’t the two best questions to use for this AR. The focus of this treatment wasn’t about picking the right
graph or reading graphs, it was really about selecting data, comparing data, looking for patterns, and generating hypotheses.

Figure 3 shows the change in ability rating for all three abilities after treatment.

![Bar chart showing score change and number of students](chart.png)

*Figure 3.* Post treatment change in score on all three questions with number of students responding, (N=33).

Overall, most students felt their ability to make, choose, and read graphs improved. There were four negative rating changes. One student that lowered his score in making the right graph explained this by stating, “...because I was introduced to a few new graph types.” Since he has more choices, it is harder to pick the right one. The other three negative changes were from one student. This person is an average student who struggles at times. This student said, “I absolutely hate graphs more than anything.” He also said that graphs make him “sad” because that it “takes work” to make them. He went on to say that TinkerPlots is the easiest way to make graphs, and he feels pretty good if he can use it to make graphs.
The eight students who improved the most with a plus three change in one or more of the skills had an average first semester grade point average (GPA) of 3.4/4.5. This is an average grade of math, social studies, and science grades in the first semester. The average for the entire seventh grade class was 3.4/4.5. The grade point range of the eight students was 2.0 to 4.2. This shows that the treatment helped a wide range of students have a large improvement. This is also shown in figure 4 which compares first semester GPA with rating change by individual. This is a graph from TinkerPlots and each circle represents a student while the different colors show the range of the attribute. The blue triangle and number is the mean.

*Figure 4. Comparing post treatment change in response to rate your ability to make a graph with first semester grade point average*
Figure 4 shows that the treatment affected students across all grade point averages which is encouraging. This implies that all students can benefit from this treatment. Of the six students with a GPA less than three, only one felt they did not improve. This student is a hard worker but struggles in class, especially on tests. He also lacks confidence and said, “I am afraid to mess up.”

I believe that the improvement is due to student’s interest and ownership of the process. One student said, “I learned that I like to work.” Figure 5 shows the comparison of students rating of ability to make a graph and GPA.

Figure 5. Comparing post treatment rate your ability to make a graph with first semester grade point average, (N=33).
Figure 5 shows that all students, regardless of GPA, can rate themselves high in the ability to make a graph, but only students with low grade point averages will rate themselves eight or lower. This implies that high grade point students are confident, and many lower grade point students are, too. It also shows that low confidence students tend to be low grade point students. All students with a GPA over 3.5/4.5 give themselves a high confidence rating.

The survey had two questions about how students feel when asked to make a graph and read a graph. I collected all the key words they used in their responses and gave them a score of zero, one, two, or three. This is shown in the table 6. The pretreatment and post treatment average score is shown in figure 6.

<table>
<thead>
<tr>
<th>Score</th>
<th>Words Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Scared, Upset</td>
</tr>
<tr>
<td>1</td>
<td>Okay, Normal</td>
</tr>
<tr>
<td>2</td>
<td>Pretty Confident, Fine, Good, Prepared, Ready</td>
</tr>
<tr>
<td>3</td>
<td>Happy, Easy, Excited, Very Confident</td>
</tr>
</tbody>
</table>
Figure 6. Average score comparing responses to feelings about reading and making graphs before and after treatment, (N=32).

The average score increased in the responses to both questions, but more in the feeling about making a graph. Once again, evidence that this AR was more about making graphs than reading graphs. The number of zeros decreased in both responses is even more significant than the average increase in both categories. Four students responded with the words scared or upset before treatment and only one after treatment when responding to how they feel when asked to read a graph. In response to how they feel when making a graph, students went from nine scared or upset responses before treatment to five after treatment. I think that both the average increase and the zero response decrease show an increase in confidence in the students.

In follow up interviews with the five students who had a low response to these questions, two said they had a low response because they do not want to make a mistake. Two of the students said they would like making graphs if they could use TinkerPlots. The fifth student said, “I am nervous that I won’t use the right data,” but once he has the right data,” I feel good about making a graph.”
The surveys show that the treatment helped the students gain an understanding in the purpose of graphs, the ability to make graphs, and confidence in making graphs. This treatment helped a wide variety of students. The surveys helped answer my two AR questions especially the one about attitude but the improvement in ability and attitude could be totally due to the practice the students got during treatment. I needed a different look.

During the genetics unit, there is a lesson were students explore hand span variation in the class. This year, I allowed the students to choose additional characteristics to measure. Some examples they chose were shoe size, height, and hair color. One class chose seven characteristics and the other chose eight. After collecting the data, the students had to find a pattern and prove or support it with a graph.

As the students collected the data for the Hand Class Data project, I heard several state that they couldn’t wait to use TinkerPlots to look at this data. Due to a scheduling conflict, I could only reserve the computer lab for one class. When I informed the one class that they would have to use pencil and paper, several groaned audibly. I was absent the day they looked for patterns and then made graphs. The teacher with the pen and pencil group told me that there was a lot of frustration and anger expressed by the students because they couldn’t use TinkerPlots. The teacher with the TinkerPlots group said the students eagerly and smoothly worked on the assignment. TinkerPlots has improved students’ attitudes towards analyzing data.

This was a unique opportunity with the Hand Class Data project to compare paper and pencil against TinkerPlots. Due to an absence, one of the students who should have
been in the paper and pencil group used TinkerPlots instead. I wanted to compare the total number of patterns made, the number of unique patterns made, and the number of students whose graphs proved their patterns. Table 7 below summarizes this data.

Table 7
Comparing the Paper and Pencil Group with the TinkerPlots Group on the HandClass Data Project in Making Patterns and Proving Patterns

<table>
<thead>
<tr>
<th>Category</th>
<th>Paper and Pencil Group N=16</th>
<th>TinkerPlots Group N=17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Patterns Made</td>
<td>25</td>
<td>57</td>
</tr>
<tr>
<td>Number of Unique Patterns Made</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td>Average Number of Unique Patterns Made</td>
<td>1.5</td>
<td>1.7</td>
</tr>
<tr>
<td>Number of Students Who Proved Pattern</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Percent of Group That Proved Pattern</td>
<td>50%</td>
<td>65%</td>
</tr>
</tbody>
</table>

The total number of patterns identified was more than double in the TinkerPlots group. I believe this is due to the ease and quickness you can manipulate data in TinkerPlots versus paper and pencil. As one student in the TinkerPlots group said, “I thought using TinkerPlots was very easy and quick. Analyzing data is made simple with this program.” Or, as a paper and pencil group student said, “It was ridiculously hard without TinkerPlots.”

The percentage of students in the Tinkerplots group that proved their patterns was higher than the paper and pencil group. I believe that the paper and pencil group would have matched or exceed the other group if they had used TinkerPlots. This group has some of the best students in the seventh grade and I will examine this later.
It is interesting to see that both groups generated about the same number of unique patterns. This implies that both groups can see the patterns, but the speed of TinkerPlots helps students find more per individual. This is shown in the figure 7.

Figure 7. Comparing paper and pencil group (PP) and TinkerPlots group (TP) in number of patterns made per individual with semester average on a 4.5 scale included. Each circle represents an individual and the colors indicate if they proved their pattern or not.

The figure shows that the TinkerPlots group generated more patterns. They generated an average of 3.1 patterns per student while the other group generated an average of 1.6 per student. Four students in the TinkerPlots group noticed that the average for the boys was higher in every attribute in the class. No one in the paper and pencil group noticed this larger pattern. TinkerPlots allows the students to search for and see more patterns because of the ease of use and speed.

There were four reasons that students did not prove their pattern: unclear, needed to use mean, data wrong, or picked wrong graph. There were three students in each group
who were unclear. It did not matter which technique you used to analyze the data if you were unclear in stating the pattern or unclear in the connection between the graph and the pattern. There were three students in each group that needed to use a mean. TinkerPlots should have been an advantage in incorporating averages into graph because it takes two mouse clicks. Once again I don’t think either technique will give an advantage if a student makes a mental mistake.

Not using the right data was the reason one student did not prove their pattern. He counted wrong when making his graph. When I showed it to him he realized his error and said, “I didn’t think it through enough and it would not have happened in TinkerPlots because it is automatic.” The last student used the wrong graph. His pattern was correct, but his triple bar graph was confusing and didn’t prove it. When I asked him about it he said his graph “wasn’t the best idea.”

Of the 14 students who did not support their pattern, seven of them also failed to do this in the Data Cards project. These students are on the lower end of the seventh grade based on GPA. The class average is 3.4 and this group is 3.0. The range of this group is 2.0-3.5. Four of these students rush through assignments and do the minimum required. TinkerPlots probably did not motivate these students for these projects. One of the students works hard and has a tendency to do too much and loses focus on the goal. TinkerPlots could be detrimental for this students due to the numerous, quick looks that it gives this student. The last two students I discuss in greater detail on page 39.

There are eight students in the seventh grade that have a GPA of 4.0 or higher. Five of the eight proved their pattern. All three that did not were in the paper and pencil
group. One student had a bar graph that made the two averages appear identical, but the average was slightly different. He said, “I should have put the numerical value.”

TinkerPlots and Excel provide tools to insert the values, but a student could still forget to do that.

The other two of the five had double bar graphs that displayed each student individually and was hard to read and did not support their pattern. I showed one student a graph I made with TinkerPlots and it showed his pattern to be wrong. I showed the other student several options that would have proved his pattern. He said, “When I hand write a graph, it’s hard to choose the right graph. I could have made it simpler.”

Once the two students with the double bar graphs made the decision to make a labor intensive graph they were stuck with it due to time. All three students said that they thought TinkerPlots would have helped them. TinkerPlots gives a student an advantage due to its ease of use and speed. It allows you to correct many mistakes, like the type of graph you choose to make, quickly.

There is another interesting pattern in the figure. There are six students with a GPA less than 3.0. Four of these students failed to prove their pattern. The two that proved their pattern were both in the TinkerPlots group. Three of the four struggles with written expression and the fourth will do the minimum to complete an assignment. TinkerPlots does not help with written expression but there are indications that it helps all kids analyze data.

After the assignment was over, I asked the students to reflect on the assignment. This was an open ended survey; the students could write what they wanted. This survey
confirms two things: students enjoy using TinkerPlots and prefer it over pen and pencil.

Table 8 below summarizes this.

Table 8
Comparing paper and Pencil Group With TinkerPlots group on Responses When Answering the Question: Reflect on the Hand Class Data Project

<table>
<thead>
<tr>
<th>Category</th>
<th>Paper and Pencil Group N=17</th>
<th>TinkerPlots Group N=16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unhappy, Frustrated, or</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Prefer TinkerPlots</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Every student in the TinkerPlots group found the assignment to be easy while only three in the pencil and paper group thought it was easy. “I thought that using TinkerPlots was very easy and quick. Analyzing data is made simple with this program,” said one student. Sixty percent of the students mentioned they would have preferred using TinkerPlots for this assignment. One student said, “Yesterdays assignment was really hard without TinkerPlots.” Eight students mentioned that they liked using their own data. A student, who struggles academically, wrote, “I liked that it was made up of data from the students and that makes the assignment fun. It was interesting to watch the different data come together as whole.” TinkerPlots improves student attitudes towards analyzing data because it is fast and easy to use. I also see an increase in attitude when students use authentic data.

I asked the students, "What is your favorite way to analyze data?" The responses are summarized in table 9.
Figure 8. Summary of student response to what is your favorite way to analyze data, $N=33$.

TinkerPlots is favored by a significant majority of the students. I personally agree with the two students that TinkerPlots is the way to analyze the data, but Excel is better at making graphs. I used TinkerPlots to analyze this data, and used Excel to make most of the graphs because TinkerPlots either can’t make the graph or it just looks better in Excel. The student who likes to use TinkerPlots to analyze and paper and pencil to make feels that paper and pencil gives him more control for making the graph.

There are two students who prefer paper and pencil. These are the two students from the group of seven that did not support hypothesis in both the Data Cards and Hand Class Data project. Both students struggle academically. One of them said, “I hate computers.” This student prefers pencil/paper because he is resistant to change. He is comfortable with things he knows and lacks confidence when trying new things. He does not read things completely, so following directions is also an issue.
I consulted with the learning consultant because the other student has a diagnosed learning disability. The main strategy this student uses to cope with the learning disability is the use of pencil and paper because he can depend on it, erase mistakes, it is slower paced, feels in control, and provides motor memory. This student does not get these things with TinkerPlots.

Our math teacher, Mrs. Ebert, has the seventh grade students complete a Consumer Research project every year. The students make a poster board and need a graph on it. I interviewed her about the graph portion. Comparing to past years, she felt that the students chose the appropriate graphs better, made better inferences, and interpreted graphs better. She said, “Students found making the data graphs was fairly easy.” This is further evidence that software improves student’s ability to analyze data.

I also surveyed the students about this project. The students did an activity for me earlier in the year and the majority of students made paper and pencil graphs even though they had been taught excel. For the math project, only four of the thirty-three students used paper and pencil. One student used TinkerPlots, eight used a website, and twenty used Excel. TinkerPlots need to be downloaded and most students haven’t done that at home but they do have access to Excel or the internet. I think the main reason that more students are using software to make graphs is they have now practiced a lot and it is familiar. They also realize it is a lot easier.

There were four students that used paper and pencil. One student felt it was more convenient. The other three students worked together. One of these students said, “We forgot how to use Excel.” His partner said, “We were too lazy.” These three all failed to
support their hypothesis in Data Cards and Hand Class Data. TinkerPlots motivates some students, but has not reached all of them.

The students used TinkerPlots to compare demographic data of at least three countries in social studies class. They were to pick a pattern, support it with a graph, and then generate a research question based on the pattern. In the past, the students used paper and pencil to complete this assignment. The students were excited to use TinkerPlots. Our social studies teacher, said, “I’ve never had students this excited about this assignment when it was paper and pencil.”

I had a planning period when she was taking one class to the computer lab, so I sat in on the assignment. The students were focused and engaged. Instead of spending time staring at tables of data and making graphs by hand, TinkerPlots allowed the students to jump right into analyzing the data. It also allowed the students to modify the data quickly. For example, one student changed population from 259,000,000 to 259 million for his graph. TinkerPlots allows students more time to analyze data and to quickly modify data. It can also shorten the time it takes to analyze data. All three are valuable to the learning experience.

I surveyed the math, computer, and social studies teachers before and after treatment. We have one teacher per subject. Including me, all four of us agree that student’s ability to make graphs and analyze data have improved. The math teacher stated, “The graphs were of a better quality than the beginning of the year.” The survey also showed we felt that student’s ability to analyze data improved. The math teacher stated, “TinkerPlots gives the students immediate visual results. It helps them see
patterns.” The social studies teacher added that they are, “much better at making and analyzing graphs.”

One purpose of the survey was to measure the effect of teacher’s attitude. All the teachers liked teaching graphing to students before and after treatment. I am the only one that did not like it before treatment, and now I enjoy teaching it with digital tools. The math teacher was not involved directly in watching the students use TinkerPlots. The other three were involved in an activity were we observed the students use TinkerPlots. We all saw the students excited. The computer teacher said, “I like the excitement that most of the kids have for TinkerPlots.” The social studies teacher added, “it’s more fun for me, if it’s more fun for them.”

The computer teacher also said, “Some of the students have become experts, which they enjoy, and I enjoy them taking a little pressure off of me.” I believe that the treatment, especially TinkerPlots improved teacher attitude because of the quality of work improved, the students were excited, and the students took ownership.

INTERPRETATION AND CONCLUSION

This project answered all my AR questions. This study provided evidence that TinkerPlots is an effective tool to improve student’s ability to analyze data, improve student’s attitude when analyzing data, and improve teacher’s attitudes when teaching analyzing data.

By using TinkerPlots in the Data Cards project, the student’s showed a 53% improvement in proving their hypothesis and a 50% increase in generating unique hypothesis. This shows an improvement in ability to analyze data by not only in proving
hypotheses but in generating unique patterns. This is due to the ability to, easily and in a short amount of time, compare more attributes, see more patterns, and create more graphs. The ease of use leads to happier students.

Also in the Data Cards project, seven students using TinkerPlots proved two or more hypothesis and one of them proved six. They all attempted to prove only one when using paper and pencil. Once again, the ease and speed of TinkerPlots leads to more data analysis which is an improvement in ability.

While the excitement the students had using TinkerPlots was my favorite part about using TinkerPlots, my second favorite thing was the self-learning aspect. The post survey showed a 57% increase in key words used in response. These words were not taught by me. The students gained a better understanding of the purpose of graphs on their own. Understanding the purpose of graphs I believe leads to increased ability. When working on projects, the students would explore TinkerPlots and find new things in the software. The students would sometime share this information with other students and if another student was stuck in TinkerPlots, another student would usually solve the problem before I could.

The student surveys showed that 73% of the students felt their ability to make graphs increased. This is supported by me, the math, the social studies, and the computer teacher who feel that the students are more capable of making graphs. This was also supported in the teacher surveys. The teacher surveys revealed that they felt that student’s ability to analyze data improved along with teacher attitude.
The Hand Class Data activity provided further evidence that TinkerPlots improves student’s ability to analyze data. All 16 students in the TinkerPlots group thought the assignment was easy while and pencil group in total patterns made, number of unique patterns made, and patterns supported. So while the practice they have done was significant on improvement, the use of TinkerPlots was important too.

The social studies teacher and the math teacher both noted an improvement in graph making and data analysis in class assignments done in their class. I believe that the use of TinkerPlots caused this improvement. More importantly, the social studies students used TinkerPlots for their assignment which means TinkerPlots can be used in multiple subjects.

At the end of the treatment, I asked the students, "What is your favorite way to analyze data?" TinkerPlots was the favorite for 31 out of 33 students. In follow up interviews, even kids that had lower ratings or feeling about making graphs said they felt ok or better if using TinkerPlots. Except for a couple of exceptions, TinkerPlots improves students’ ability to analyze data.

Through observations all four teachers agreed that TinkerPlots improved student’s attitudes towards graphing. We all noted that they were excited to use TinkerPlots. I think this is due to its ease of use, speed, and the ability to individualize projects. This student excitement led to an improved teacher attitude.

VALUE

The most important value of this AR was that TinkerPlots generated excitement and enthusiasm in most students. Some of the best class lessons I had this year was when
we were using TinkerPlots. There is nothing better than excited students. It creates a great learning environment.

I believe the second most important value is that TinkerPlots affects all types of students and across several subject areas. Students in social studies, math, and science can use it to create graphs and analyze data. The software was designed for fourth grade and up so all students in grades four through eight could be affected by this software.

TinkerPlots could help students meet standards set by the National Council of Teachers of Mathematics. The software could help introduce and teach fourth and fifth grade students how to represent and interpret data. It could help middle students learn about distributions and probability. These are two areas in TinkerPlots I did not have a chance to explore.

Most science standards are now emphasizing performance expectations and these expectations are of a higher order of thinking than skills like making a graph. The standards are also emphasizing the interconnectedness of content areas. TinkerPlots is a tool that allows students to get past the grind of making graphs and get onto the task of looking for those connections. Tinkerplots also allows students multiple looks at the data and this gives students opportunities to think about the connections and generate questions that cross multiple disciplines.

TinkerPlots not only had value for the students and teachers for content learning, it has also become a valuable tool in analyzing data and identifying patterns in students. For example, I used TinkerPlots to see that there is a strong correlation between standardized test scores and academic achievement in my students. I also used it after the
sixth grade did unusually bad on a test. There was a strong correlation between those who did not use Quizlet and low multiple choice scores. Quizlet is an online vocabulary learning tool. I also saw that the majority of low level students did not use Quizlet and these are the students who needed the most. I adjusted my teaching based on this discovery. My principal has expressed interest in expanding the use of TinkerPlots in these areas.

The value of TinkerPlots in answering my AR questions was important, but almost as important is the role it played in differentiation and authentic data. Using authentic data increased student excitement and engagement. While authentic data can be used with paper and pencil, the ease and speed of TinkerPlots allows for more projects using authentic data. The use of TinkerPlots allows students to explore patterns that interest them, express themselves in different ways, and get to the end along different paths and speeds.

Next year, I want to incorporate TinkerPlots into school curriculum for grades five through eight in science, social studies, and math classes. It was a unique situation the allowed me to use TinkerPlots for free and as of this writing I do not know the cost of TinkerPlots for next year. We may not be able to afford it.

Excel will continue to be taught and used for graphing especially as we continue our goal of cloud based computers and more platforms for the students to use during classes. The speed and neatness of using Excel are beneficial to the students and the teachers.
Although the whole process of this Capstone was long and exhausting, I am grateful for being introduced to TinkerPlots. It is quick and easy to use. Not only is it beneficial for teachers and students in the classroom, I plan on continuing to use it to monitor my students and guide my teaching. That is the goal of Action Research.


APPENDIX A

EXCEL TRAINING
How to create a graph

Open up Microsoft Excel and type in your data in the following format:

<table>
<thead>
<tr>
<th>x-data</th>
<th>y-data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Select the data, then click on the Insert tab. Click on the Column graph. Choose from 2-D, 3-D or cylinder column graphs. Your chart must have a title and axis titles. (Make sure to include specifics about numbers: in years, per 100,000 people, etc.) To insert titles, click on the Layout tab, click on Chart Title or Axis Titles. If you need to change the numbers on the axis, you can right click and then click on Format axis. Your finished chart should look similar to the one below.

If there is time after you have completed the graph, you may change colors, fonts, move the legend, etc. Use the Home tab to change colors of the columns of your graph. Copy and paste this graph into a Word document.

Pie Chart
Enter data in the same format as above. Select the data. Click on the insert tab. Choose a pie graph.
APPENDIX B

SCIENCE WORLD SKILL SHEETS
SUPER SNACKS

In "Name That Element" (p. 20), you learned that in order to work properly, your muscles and nervous system need the element potassium. After a sweaty workout, you may need to replenish this element by eating foods that contain it. The table below shows some foods that contain relatively high amounts of potassium. Use the data in the chart to make a bargraph, then answer the questions that follow.

<table>
<thead>
<tr>
<th>Food</th>
<th>Serving Size</th>
<th>Potassium Content (milligrams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almonds</td>
<td>1 ounce</td>
<td>200</td>
</tr>
<tr>
<td>Banana</td>
<td>1 medium</td>
<td>422</td>
</tr>
<tr>
<td>Orange</td>
<td>1 medium</td>
<td>237</td>
</tr>
<tr>
<td>Prunes</td>
<td>1/2 cup</td>
<td>637</td>
</tr>
<tr>
<td>Raisins</td>
<td>1/2 cup</td>
<td>598</td>
</tr>
<tr>
<td>Spinach, cooked</td>
<td>1/2 cup</td>
<td>420</td>
</tr>
<tr>
<td>Sunflower seeds</td>
<td>1 ounce</td>
<td>241</td>
</tr>
<tr>
<td>Tomato</td>
<td>1 medium</td>
<td>292</td>
</tr>
</tbody>
</table>

Source: Linus Pauling Institute, Micronutrient Information Center, Oregon State University

GRAPH IT

Use a separate sheet of paper to draw a bar graph showing the amount of potassium in one serving of each food in the chart. Don’t forget to label the x- and y-axes and give your graph a title.

ANALYZE IT

1. Which food has the most potassium in one serving? The least?

2. How much potassium does 1 cup of cooked spinach contain?

3. How many whole oranges would you need to eat to take in 1 gram of potassium? (Remember: 1 gram = 1,000 milligrams)

4. Based on the items listed in the chart, which food group do you think contains the most high-potassium foods?

5. Suppose you wanted to prepare a high-potassium meal after exercising. What would you make?
MUMMY MAKEUP

In "Mysterious Mummies" (p. 8), you read about scientists studying the world’s oldest-known mummies from Chile. To learn more about how the mummies were made, the scientists analyzed materials in and on the mummies, including clay inside the bodies and black paint on the mummies’ masks. By determining which compounds (substances made of two or more elements that are chemically combined) are in these materials, the scientists were able to learn more about where the ancient people found their mummy-making materials. The chart below, titled "Compounds found in Chilean Mummies’ Clay Layer," shows the chemical compounds found in the clay layer beneath the black paint on the mummies. Read the chart and then answer the questions below.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Chemical Name</th>
<th>Percent in the Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>Aluminum oxide</td>
<td>13</td>
</tr>
<tr>
<td>CaO</td>
<td>Calcium oxide</td>
<td>3</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>Iron oxide</td>
<td>7</td>
</tr>
<tr>
<td>K₂O</td>
<td>Potassium oxide</td>
<td>4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>Silicon dioxide</td>
<td>68</td>
</tr>
<tr>
<td>Other</td>
<td>–</td>
<td>5</td>
</tr>
</tbody>
</table>

SOURCE: ARRÁIZ ET AL., 2010

GRAPH IT

Use a separate sheet of paper to create a pie chart that shows the percentages of the compounds found in the Chilean mummies’ clay. Don’t forget to label the pie slices and give your chart a title.

ANALYZE IT

1. What is the chemical name for K₂O?

2. Which compound makes up 7 percent of the compounds found in the mummies’ clay?

3. Which compound accounts for more than half of the compounds found in the clay?

4. Suppose the scientists are trying to determine which of two clay-type rocks was the likeliest source for the clay in the mummies. They analyzed the rocks, and then listed the percentages of the compounds in the samples in the charts below, labeled "Sample A" and "Sample B." Which sample do you think is the likeliest source for the clay in the mummies? Explain your answer.

Sample A

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>22</td>
</tr>
<tr>
<td>CaO</td>
<td>13</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>7</td>
</tr>
<tr>
<td>K₂O</td>
<td>4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>50</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

Sample B

<table>
<thead>
<tr>
<th>Compound</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃</td>
<td>12</td>
</tr>
<tr>
<td>CaO</td>
<td>2</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>8</td>
</tr>
<tr>
<td>K₂O</td>
<td>4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>67</td>
</tr>
<tr>
<td>Other</td>
<td>7</td>
</tr>
</tbody>
</table>
APPENDIX C

TINKERPLOTS BASICS
TinkerPlots Basics

TinkerPlots Tutorial 1

In this tutorial, you will learn to:

- Enter data
- Use Sample Documents
- Stack and order data in different ways
- Create common graphs
- Use different icon types to illustrate data
- Import data from an external source

You may also wish to watch the movies "TinkerPlots Basics" and "Making Common Graphs" to enhance your knowledge of these topics.

Entering Data

For this tutorial, you will look at data collected from high school students in the United States in 1990. First you'll learn how to enter your own data, and then you'll explore a sample data set included with TinkerPlots.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Birth Year</th>
<th>Height</th>
<th>Homework</th>
<th>Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>72</td>
<td>71 inches</td>
<td>4 hours/week</td>
<td>No</td>
</tr>
<tr>
<td>Female</td>
<td>74</td>
<td>65 inches</td>
<td>10 hours/week</td>
<td>Yes</td>
</tr>
<tr>
<td>Male</td>
<td>72</td>
<td>72 inches2</td>
<td>3 hours/week</td>
<td>Yes</td>
</tr>
</tbody>
</table>

To enter this data set:

1. Choose File | New to open a new TinkerPlots document.

2. Drag data cards from the object shelf into the document.

3. To add an attribute into the data cards, such as Gender or BirthYear, double-click and enter the name of the attribute. You can't enter spaces, so you'll need to
distinguish multiple words with capital letters, hyphens, or underscores. For example, you might enter BirthYear or Birth-Year or Birth_Year. Enter all of the attributes from the table above into your data cards.

4. Next, fill in the first student's values for each attribute. Click in the Value column, in the cell next to Gender, and enter "Male." Fill in the values for the other attributes. You can use the Unit column to record units, such as "inches" or "hours/week." Note that each data card holds the data for one person, or case.

5. Click the right-arrow at the top of the data cards to create a new data card. Notice that the values in the Attribute and Unit columns are automatically filled in.

6. Enter the values for the next two students into two data cards.

7. You can also enter data into a case table. Click the data cards window to select it. Then drag a table from the object shelf into your document. Because you selected the data cards before dragging in the table, the attributes and cases in the data cards will appear automatically in the table.

8. Enter these next two cases directly into the table. Notice that as you add cases to the table, the same cases are added to the data cards.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Birth Year</th>
<th>Height</th>
<th>Homework</th>
<th>Job</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>74</td>
<td>68 inches</td>
<td>15 hours/week</td>
<td>No</td>
</tr>
<tr>
<td>Female</td>
<td>72</td>
<td>62 inches</td>
<td>10 hours/week</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Exploring a Sample Document
The data you’ve entered so far were taken from one of the sample data sets included with TinkerPlots. Using all of the data in this data set will give you more to explore.

9. Choose File | Open Sample Document. From the Social Studies folder, open the file US Students.tp. You may also want to explore what other data sets are available to you.

This file contains data cards, a plot, and two text boxes. The text box on the left describes the data that were collected. The other text box asks questions you might want to explore using the collected data. Let's look at some different ways you can organize the data.
10. Each circle, or *case icon*, in the plot represents one case—in this instance, a person. Click a case icon in the plot. Notice that this case automatically appears in the data cards. Click another case icon, and notice that a different data card is displayed.

11. Click the attribute *HomeWork* in the data cards. This colors the case icons according to their *HomeWork* value. Because *HomeWork* is a numeric attribute—number of hours of homework per week—you see a color gradient next to the attribute in the data cards. Lighter colors indicate lower numerical values, and darker colors indicate higher numerical values.

12. Click a case icon and drag it to the right. As you do so, the cases will separate into bins. Keep dragging the case icon to the right, and the cases will fully separate along a horizontal axis.

13. Click the **Stack cases vertically** button in the upper plot toolbar to stack the case icons.
14. Now click the attribute *Gender* in the data cards to color the case icons by gender.

15. Click the **Order cases vertically** button to order the icons by gender.

16. Click an orange case icon and drag it up. This will separate the data into two separate plots by gender. What do you observe?

Experiment with making observations about data by choosing different attributes, stacking them, and ordering them. You can click the **Mix-up** button in the lower-left corner of the plot to start over.

**More About Plots**

Now you'll look at some other ways you can plot data in *TinkerPlots*. First, you'll make a pie graph to see if girls or boys are more likely to have a curfew.

17. Click the **Mix-up** button to scramble the case icons.

18. Click the attribute *Curfew* in the data cards (you may need to scroll down to find it), and drag it to the horizontal axis of the plot. A black rectangle will appear in the locations where you can drop the attribute. What do you observe so far?

19. Change the **Icon Type** to "Fuse Circular." If you see two circles, click the one on the right and drag it to the left until the circles combine.

20. Click the **Key** button in the upper plot toolbar to show what the colors represent. Then click one of the **Order** buttons to estimate how many students have a curfew. It looks like about two-thirds of the students have a curfew.
21. Click *Gender* in the data cards. Then click one of the slices of the pie and drag it to the right to make two pie graphs.

22. Click *Curfew* again in the data cards. Comparing the two graphs, is it more likely that a male or a female student will have a curfew?
Next, let's make a bar graph to see how much money students were carrying when the data was collected.

23. Click the **Mix-up** button to start with a fresh plot.

24. Click *MoneyOnYou* in the data cards and drag it to the vertical axis. What do the five case icons on the top represent?

25. Click and drag a case icon up to fully separate the values.

26. In the lower plot toolbar, change the **Icon Type** to Value Bar Vertical. Then click the **Order cases horizontally** button. To see individual cases, drag the **Icon Size** slider (in the lower plot toolbar) to make the case icons smaller. What observations can you make about how much money these students were carrying?

Finally, let's use a scatter plot to see if there is a relationship between two variables: the amount of time students spend doing homework, and their age.

27. Click the **Mix-up** button to start with a fresh plot.

28. Click *HomeWork* in the data cards and drag it to the horizontal axis. (You may want to use the **Icon Size** slider to adjust the case icon size again.) Then click and drag a case to the right to fully separate the values.

29. Click *BirthYear* and drag it to the vertical axis. Then click and drag a case up to fully separate the values, creating a scatter plot. From this graph, does it appear that older students spend more time doing homework?

30. Choose another two variables to explore, and see if there appears to be a relationship between them.

**Importing Data**

Now that you have learned some of the basics of *TinkerPlots*, you will learn how to import data from an outside source. *TinkerPlots* can import data from a variety of sources, including a spreadsheet or the Internet. The data need to be organized in columns.

31. Choose **File | New** to open a new *TinkerPlots* document.

32. Open an internet browser, and go to the DASL library at [http://lib.stat.cmu.edu/DASL](http://lib.stat.cmu.edu/DASL). Click **Data subjects**, select **Food**, and click and hold **Hot**
dogs Datafile and drag it into the TinkerPlots document. This will import the data at this URL into TinkerPlots. A new set of data cards will appear.

33. Click through the data cards to make sure the data appears correctly.

34. If you like, use some of your new skills to explore plots of these data.

To import data from a Microsoft Excel file, open the file and select the data you want to use. Then choose Edit | Copy. Return to TinkerPlots and click to select data cards or a case table. In TinkerPlots, choose Edit | Paste.

In the next tutorial, "Analyzing Data," you will learn how to explore a data set to determine analytically whether there are interesting trends.
APPENDIX D

TINKERPLOTS ANALYZING DATA
Analyzing Data

TinkerPlots Tutorial 2

In the tutorial TinkerPlots Basics, you learned how to enter data into TinkerPlots and make basic plots. In this tutorial, you will learn to:

- Measure averages
- Use the ruler tool to measure distances
- Use dividers and hats to estimate central clumps
- Use counts to see the number or percent of data in a bin, division, or plot
- Use the color meter to see the average color in a selected area of the graph

Exploring Averages and Distributions


2. You will see data cards with information about each state in the United States, a text box describing the attributes, and a plot. Read the description of the RedBlue_State attribute to see how RedState and BlueState are defined in this data set.
   You can use TinkerPlots to compare educational spending in red and blue states.

3. Find Ed_Spending in the data cards and drag this attribute onto the horizontal axis of the plot. Drag a case icon to the right to fully separate the values, and stack the cases vertically.

4. Click RedBlue_State in the data cards, and then drag a red case icon (in the plot) up to separate the values.

5. Click the Mean button to display the average for each group. You can also use the Median button to show a different measure of center.

6. To show the numeric value of the mean, click the Average Options button and choose Show Numeric Value(s). You can see that the mean educational spending
per student in the blue states is greater than in the red states.

7. To determine how much greater, click the **Ruler** button in the upper plot toolbar. Move the ends of the ruler to the two means—the means of the two plots. You can lock the ends of the ruler onto the means by clicking on the ruler's end line and dragging the cursor to the mean symbol itself. A circle around the mean marker indicates that you are locked onto that value. What is the difference of the averages?

8. Click the **Ruler** button and the **Mean** button again to turn off the ruler and the means.

9. Click the **Dividers** button.
Click and drag the top corners of the divider to change its size and position. Adjust each divider so that it includes the "center clump" of data.

10. Now click one of the Counts buttons to display how many cases are in each divider. You can click N to display the number, or % to display the percent of data in each area.

11. Click N or % again to turn off counts.

12. Click the Hats button to display a hat plot of the data. The center clumps in your dividers should be close to where the hat is, while the "brim" reaches to the data points on either side of the center clump.

13. Adjust the dividers to match the hats. About what percent of data lies within the hat? About what range of spending lies within the hat for red states? Blue states? This is called a Percentile Hat. You can explore other types of hats by clicking the Hat Options button.
Using the Color Meter

Now you’ll use the color meter to look at population density in the United States.

14. First click the **Mix-up** button to clear your plot.
15. Click *Longitude* in the data cards and drag it to the horizontal axis. Fully separate the values.
16. Click *Latitude* in the data cards and drag it to the vertical axis. Fully separate the values. You should see a plot that somewhat resembles a map of the United States. What do the two left-most cases represent?

![Plot of US States with latitude and longitude coordinates](image)

17. Click *PopDensity* to color the cases.

18. Click the **Meter** button to turn on the color meter. The color meter shows the color representing the average value for cases within its rectangle.

19. Make the color meter narrower by dragging one edge.

20. Click within the color meter and drag it across the plot. Do you notice any trends as you drag it to the right? Which areas of the country appear to be the most densely populated?
21. You can also create snapshots of the color meter. Move the color meter to the left edge of the plot, and double-click inside it. Double-click again to create another snapshot. Repeat this until the snapshots fill the plot. Ignoring snapshots with only 1 or 2 cases, do you notice any trends?
22. Click the **Meter** button again to turn the color meter off. You can also use the color meter's Line Trace to analyze population density.

23. Click **PopDensity** and drag it to the vertical axis.

24. Click the **Meter** button to turn on the color meter, and resize the color meter to be about half as wide.

25. Click the **Color Meter Options** button and choose **Line Trace**.

26. Click and drag the color meter from left to right across the plot. As you do so, observe the line being drawn. It represents the average value within the color meter as you drag it across the plot. Does this value correspond to your answer to Question 20?
APPENDIX E

WHO HAS THE HEAVIEST BACKPACKS?
Who Has the Heaviest Backpack?

OVERVIEW

The main focus of this activity is comparing groups—comparing backpack weights for students in different grades and comparing backpack weights for boys and girls. The level of sophistication that students use for these comparisons will vary by grade level, but all comparisons should include some descriptions and use of centers, such as means or center clumps. Later grades may also focus on differences in spread among the groups.

The activity Is Your Backpack Too Heavy for You? extends the themes of this activity and could be used in conjunction with it.

For grades 4–5, this activity also provides a good opportunity to distinguish between categorical and numerical data. Students should be able to identify the categorical attributes (Name, Gender, Grade) from the numerical attributes (BodyWeight, PackWeight). If you use this activity to introduce TinkerPlots, you can have students explore how TinkerPlots uses color for different types of attributes and what happens when you separate categorical versus numerical attributes.

For all grades, students should explore different ways of separating, ordering, and stacking the data, creating a variety of graphical representations. They should observe how different plots highlight different aspects of the data and choose a plot that helps them tell the story they want to tell.

Activity Time: One class period

Objectives

- Compare related sets of data.
- Make observations about differences between groups.
- Distinguish between categorical and numerical data.
- Describe the shape and other important aspects of numerical data.
- Justify conclusions based on data.
- Represent data with graphs.

Common Core Standards Addressed

Understand that a set of data collected to answer a statistical question has a
distribution which can be described by its center, spread, and overall shape.

*Grade 6, Statistics and Probability Standard 2*

Summarize numerical data sets in relation to their context.

*Grade 6, Statistics and Probability Standard 5*

Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.

*Grade 6, Statistics and Probability Standard 2*

Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge variation in estimates or predications.

*Grade 7, Statistics and Probability Standard 2*

Use measures of center and measures of variability for numerical data from random samples to draw informal comparative inferences about two populations.

*Grade 7, Statistics and Probability Standard 4*

**Prerequisites**

- Students need to know that TinkerPlots collects data in *data cards* and that *plots* allow you to display and organize data. These are introduced in the movie “TinkerPlots Basics.”

**Materials**

- Who Has the Heaviest Backpacks? worksheet (one per student)
- Heaviest Backpacks.tp

**LESSON PLAN**

**Think About It (10 minutes)**
Hand out the Who Has the Heaviest Backpacks? worksheet.

Encourage students to work in pairs or small groups to write answers for the Think About It questions, or have students write individual answers and then discuss them in groups. Involving students in group discussions will foster communication, help make apparent common expectations about the data and questions, and illuminate alternative ideas.

**Plot and Investigate (15 minutes)**

Have students move to computers and open the document **Heaviest Backpacks.tp** to explore backpack weight data.

In exploring Step 6, students in grades 4–5 should, at the least, use a plot that is ordered by PackWeight and colored by Grade. Students should then note that first-graders (light-pink) tend to be on the far left (lower weights); third-graders (pink) tend to be in the middle left; fifth-graders (red) tend to be in the middle right; and seventh-graders (dark red) tend to be on the far right (higher weights).

Students may separate the case icons into bins, as shown on the next page. Many students will want to compare the counts in common bins: “There are more students that carry backpacks above 16 pounds in grade 7 than in any other grade. So students in grade 7 carry heavier backpacks.” However, because the data do not include the same total number of students in each grade, this is not a valid argument. Students should instead think in terms of fractions or percents (“68% of students in grade 7 carry backpacks over 15 pounds, but only 18% of students in grade 5 and 0% in grades 1 and 3 carry backpacks over 15 pounds. So students in grade 7 carry heavier backpacks”). Alternatively, students could focus on center clumps (“Grade 1 cluster around 1–5 pounds. Grade 3 cluster around 6–10 pounds. Grade 5 cluster around 6–15 pounds. And grade 7 cluster around 16–25 pounds.”)
Some students, especially those in grades 6–8, will fully separate both Grade and PackWeight. They might use various ways to highlight and argue why the data show students in higher grades tend to carry heavier backpacks. The plot on the next page uses dividers to highlight center clusters. Here, the clusters in the gray divisions show an increase as the grades increase.

![Plot](image)

Depending on their proficiency with TinkerPlots, students in grades 4–5 might include range hats, the mode, or the median to further support their answer. Students in grades 6–8 might use box plots or the mean.

Commend students who try other plots that clearly support their conclusions, including students who are able to construct plots that support alternative conclusions. Encourage older students to refine their conclusions by using precise statements, such as “50% of seventh-graders have a backpack between 12 and 21 pounds.”
Wrap-Up (10 minutes)

Have a couple of students with different kinds of plots present them to the class. You can do this by having students walk around from computer to computer, or, if you have remote connection, by displaying their computer screens on the overhead display. Discuss how different plots help to answer the questions posed in Steps 7 and 9.

Extensions (optional)
1. Have students conduct their own study, collect data about backpacks at your school, and analyze the results. Compare the results from your school with the results for the data in Heaviest Backpacks.txt. You may want to do this along with a talk about samples and populations, discussing whether students think data from any one school are likely to be representative of schools across the country. Students could even plan ways to collect more representative data (for example, by collecting data at several different schools or by gathering statewide or nationwide data via the Internet).

2. Hold a discussion about ways students could lighten their backpacks or about the proper way to carry a backpack to minimize stress. See the links in the TinkerPlots Online Resource Center for more information. If students conduct their own study, they may want to collect additional data about the way each student carries his or her backpack and whether each student has experienced back pain.

3. Discuss outliers. For grades 4–5, ask students what they think an outlier is, and then have them identify data values that might be outliers. (Faith, the seventh-grader with the 39-pound backpack, is an obvious outlier.) Rather than focusing too much on the specific definition of an outlier, encourage students to consider whether the outliers’ values are correct or not. Sometimes values that are extremely far away are errors, while other times they are actual values and thus of particular interest. More typically, as is the case here, there is no way to tell for certain.

Students in grades 6–8 who used the mean or median to summarize the data could delete the outliers from the collection or change their values and see how this affects the average.

4. Ask questions that challenge students to predict cases that were not sampled. For example, “Judy is a seventh-grader. She was absent on the day these data were collected. If you had to guess the weight of her backpack, what would you guess?” You can also have students make predictions for whole groups: “Suppose we measure the backpack weights of
second-graders at the same school. What would the average weight be? Make up a reasonable collection of 20 cases for the second-graders.” Students can add these cases to the data set.

**Answers**

1. Answers will vary depending on grade level and estimation skills. Many students will want to give a range for an answer (for example, “5 to 10 pounds”), and this is perfectly acceptable; there is no reason to force students into giving a single number. As guideposts for answers, the data in **Heaviest Backpacks.tp** have a mean of 10.2 pounds and a median of 8 pounds. The middle 50% of the values range from about 5 to 14 pounds. Students may have trouble estimating weights in pounds, so you may want to have some reference weights available, such as 3-, 5-, and 10-pound weights from your gymnasium or 5- and 10-pound bags of sugar.

2. Students will likely guess that students in higher grades carry heavier backpacks. Explanations may include heavier books in higher grades, more books or homework in higher grades, or additional items such as sports equipment.

3. Some students might guess that girls carry heavier backpacks because they are (stereotypically) more studious; some might guess that boys carry heavier backpacks because they (stereotypically) want to show how strong they are, or carry extra items such as sports equipment; and some might think the weights are the same because both boys and girls are in the same classes and have the same books.

5. 79 students. Students can find this answer from the upper-right corner of the data cards, by counting the circles in the plot, or by adding counts to the plot.

7. Yes, students in higher grades tend to carry heavier backpacks than students in lower grades. Explanations must include how the plot supports their answers.

9. Answers will vary depending on the plots and statistics used. Again, students must explain how the plot supports their answers.

A simple plot ordered by PackWeight and colored by Gender may show no noticeable difference between boys and girls. Even a more sophisticated plot, such as a stacked dot plot (see below), may show little or no difference. Students might explain that these plots show about the same number of boys and girls with heavy and light backpacks, or that the clusters are located in
about the same places.

If older or advanced students use hat plots, the median, or the mean, they may notice that boys carry slightly heavier backpacks than girls. For the plot below, a student might say, “The median for boys is 8.5 and the median for girls is 7, so boys carry heavier backpacks.” Even so, some students may feel that the difference is not significant enough and still say that boys and girls tend to carry about the same amount of weight in their backpacks. (In fact, this is what a statistician would likely say as well.)

Note: So that students are able to create two plots in their document—one for Step 5 and one for Step 6, you may need to show them how to use the lock icon Key to lock the plot color (as shown in all of the plots above).
Many students develop back problems. Doctors believe that these problems are caused by the heavy backpacks students carry. Sometimes the way students carry their backpacks also hurts their backs.

In this activity you will look at data about students in grades 1, 3, 5, and 7 and decide which students carry the heaviest backpacks.

The data you’ll look at were collected by students. They went to one classroom in each grade at a school and had students weigh themselves and their backpacks.

At right is the data for Angie, a girl in first grade. The card shows that she weighs 45 pounds and her backpack weighs 4 pounds. (The “lb” you see in the Unit column is the abbreviation for pounds.)

**Think About It**

Before you look at data, think about what you expect to see. You probably already have some ideas about what these data look like.

1. About how many pounds do you think a student’s backpack weighs, on average? (Include the weight of the backpack and everything in it.)

2. Which students do you think usually carry heavier backpacks—students in higher grades (grades 5 and 7) or students in lower grades (grades 1 and 3)? Explain.

3. Which students do you think usually carry heavier backpacks—girls or boys? Explain.
Who Has the Heaviest Backpack? (continued)

Plot and Investigate

Now you’ll look at the data to see what they say.

4. Open the document Heaviest Backpacks.tp. You should see a plot and a stack of data cards like the one on the previous page.

5. How many students do you have data for?
   ____________ students

6. First you’ll look at whether students in the higher grades tend to carry heavier backpacks than students in the lower grades. Make a graph that helps you answer this question. Include a copy of your graph with your assignment.

7. Which students usually carry heavier backpacks—students in higher grades or students in lower grades? Explain. Your answer should say how your plot backs up your conclusion.

8. Next you’ll look at whether girls or boys tend to carry heavier backpacks. Make a graph that helps you answer this question. Include a copy of your plot with your assignment.

9. Which students usually carry heavier backpacks—girls or boys? Explain. Your answer should say how your graph backs up your conclusion.
APPENDIX F

DATA CARDS
<table>
<thead>
<tr>
<th>Name</th>
<th>Jennifer Rado</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
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<tr>
<td>Favorite Activity</td>
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<td>Eye Color</td>
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<td>Favorite Activity</td>
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<td>Eye Color</td>
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<td>Favorite Activity</td>
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<td>Age</td>
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<td>Favorite Activity</td>
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<td>Name</td>
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<td>John Smith</td>
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<td>David Jones</td>
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<td>Andrew Williams</td>
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<td>Anna Smith</td>
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<tr>
<td>Name</td>
<td>Age</td>
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<td>-------------------</td>
<td>-----</td>
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<td>Simon Khan</td>
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<td>Rosemary Black</td>
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<td>Brian Wong</td>
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<td>Adam Henderson</td>
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<tr>
<td>Name</td>
<td>Janelle McDonald</td>
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<td>---------------------</td>
<td>---------------------------</td>
</tr>
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<td>Age</td>
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<tr>
<td>Favorite Activity</td>
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<td>Favorite Activity</td>
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APPENDIX G

PRE STUDENT GRAPHING SURVEY
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

What do you think a graph is?

Can you give an example of a graph that you used recently?

Why are graphs made?

Do you think graphs are important? Why or Why not?

What are the names of the different types of graphs?

When do you use each type?
Why do you think information is often presented in graphs instead of just in a list or table?

How often did you make graphs at school last year? Circle one

Never
1-3 times per month
1-2 times per week
3 or more per week

In what classes? Circle

Science
Math
Social Studies
Language Arts

How often did you read graphs last year? Circle one

Never
1-3 times per month
1-2 times per week
3 or more per week
In what classes? Circle all that apply.

Science
Math
Social Studies
Language Arts

How do you feel when a teacher asks you to make a graph? Why do you feel that way?
How do you feel when a teacher asks you to read a graph? Why do you feel that way?

Can you remember a time when graphing was explained well to you? Please describe and tell why that lesson helped you understand.

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to make a graph?

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to make the right graph for the situation?

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to read a graph?
Can you share anything other ideas that might help me help student with graphing? What would you suggest?
APPENDIX H

POST GRAPHING STUDENT SURVEY
Participation in this research is voluntary and participation or non-participation will not affect a student’s grades or class standing in any way.

What do you think a graph is?

Why are graphs made?

Do you think graphs are important? Why or Why not?

Why do you think information is often presented in graphs instead of just in a list or table?

How do you feel when a teacher asks you to make a graph? Why do you feel that way?
How do you feel when a teacher asks you to read a graph? Why do you feel that way

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to make a graph?

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to make the right graph for the situation?

On a scale of 1-10, 10 being very confident and 1 no confidence, how do you rate your ability to read a graph?

What tools or strategies helped you over the last couple of months? Explain why.

Do you have any other ideas how the teachers can help you with graphing?
APPENDIX I

PRE-TEACHER SURVEY
Teacher Survey

Name: 

Grade: 

Certifications: 

Subjects taught and years teaching each: 

Please respond to the following items by drawing a circle around the response that most closely reflects your opinion:

1. I believe that my students know how to make graphs

   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

2. Why did you answer the way that you did in the above?

3. I believe that my students know how to read graphs

   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

4. What might be some indicators of this?

5. I believe that my students are confident in making graphs

   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

6. I believe that my students are confident in reading graphs

   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree
7. I enjoy teaching graphing to students

Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

8. Why did you answer the way you did in the above?

9. I enjoy giving graph making assignments to my students

Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

10. I enjoy giving graph reading assignments to my students

Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

11. I think the ability to read graphs is important

Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

12. Why did you answer the way you did in the above?

13. I think the ability to make graphs is important

Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

14. I think my student’s graph reading skills need to be improved
15. I think my students graph making skills need to be improved

16. Any additional comments about graphing and students?

17. If you were going to give one hint to a teacher about to teach a graphing unit, what would that hint be?

18. If you were asked the biggest reason that students struggle with graphing, what would that reason be?
APPENDIX J

POST TEACHER SURVEY
Post Teacher Survey

Name: 
Grade: 

Please respond to the following items by drawing a circle around the response that most closely reflects your opinion about the 7th grade students:

1. I believe that my students know how to make graphs
   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

2. I believe that my students know how to read graphs
   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

3. I believe that my students are confident in making graphs
   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

4. I believe that my students are confident in reading graphs
   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree

5. What has changed from the beginning of the year?

6. I enjoy teaching graphing to students
   Strongly Agree  Agree  Undecided  Disagree  Strongly Disagree
7. I enjoy giving graph making assignments to my students

Strongly Agree    Agree    Undecided    Disagree    Strongly Disagree

8. I enjoy giving graph reading assignments to my students

Strongly Agree    Agree    Undecided    Disagree    Strongly Disagree

9. Has your enjoyment changed from the beginning of the year?

11. Why did you answer the way you did in the above?

12. I think my student’s graph reading skills need to be improved

Strongly Agree    Agree    Undecided    Disagree    Strongly Disagree

13. I think my students graph making skills need to be improved

Strongly Agree    Agree    Undecided    Disagree    Strongly Disagree

14. What changes have you seen in the 7th grade students graphing skills this year?
15. What value do you see in the use of TinkerPlots?

16. Any other comments?
APPENDIX K

IRB EXEMPTION FORM
INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 0000165

MEMORANDUM

TO: Thomas O'Leary and Wali Woolbaugh
FROM: Mark Quinn, Chair
DATE: October 21, 2014
RE: "The Effects of Graphing Software on Students' Ability to Analyze Data" [TO102114-EX]

The above research, described in your submission of October 21, 2014, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior; unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

(b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

(b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

(b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs, (ii) procedures for obtaining benefits or services under those programs, (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

(b) (6) Taste and food quality evaluation and consumer acceptance studies, if wholesome foods without additives are consumed, or if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.
APPENDIX L

TREATMENT AND DATA COLLECTION TIMELINE
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<tr>
<th>Week of:</th>
<th>Activity</th>
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<tbody>
<tr>
<td>9/22/14</td>
<td>Student Survey</td>
</tr>
<tr>
<td>10/13/14</td>
<td>Teacher Survey</td>
</tr>
<tr>
<td>10/20/14</td>
<td>Inter views, Excel Training, Basic Skills Probe and Quail Probe</td>
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<td>10/27/14</td>
<td>Sugar Probe</td>
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<td>11/17/14</td>
<td>Data Cards Paper</td>
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<td>11/24/14</td>
<td>Minute Paper</td>
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<td>TinkerPlots Training</td>
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<td>12/8/14</td>
<td>TinkerPlots Practice and Muddiest Point</td>
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<td>1/5/15</td>
<td>Data Cards TinkerPlots</td>
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<td>Data Cards TinkerPlots and Reflection Paper</td>
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<td>Quail with TinkerPlots and Survey</td>
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<td>2/9/15</td>
<td>Hand Data</td>
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