INCORPORATING ACTIVE LEARNING STRATEGIES FOCUSED ON

CONTEXTUAL DATA ANALYSIS TO IMPROVE STUDENT

ENGAGEMENT, DATA LITERACY AND

CONCEPTUAL UNDERSTANDING

IN MIDDLE SCHOOL SCIENCE

by

Samantha Jane Berg

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

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This project compares two different teaching styles and the effects they have on student engagement, data literacy and conceptual understanding. Two sections of 8^{th} grade students learned about the weather and atmosphere through traditional methods of formal note taking and follow up activities while the treatment group consisted of two sections of 8^{th} graders learned through information given in the context of labs and investigations. Data was collected through engagement surveys, data literacy pre and post assessments, a unit test and a unit project. The results showed a greater increase in student engagement for the treatment group. The treatment group also showed greater improvement in conceptual understanding and data literacy.

INTRODUCTION AND BACKGROUND

I teach at Twin Cities Academy in St. Paul, MN on the east side of town which is known more for its diversity and crime. The student body is comprised of a diverse group that ranges ethnically and economically which can be challenging at times. At Twin Cities Academy our student demographics are: 42% Caucasian, 27% Black, 18% Hispanic, 12% Asian and 1% American Indian. Of the roughly 600 students who attend our school 7% are ELL, 13% are part of the SPED program and 46% qualify for free and reduced lunch. My school is a public charter school that is historically known for rigor and for helping any student get into college, 98% of our graduates attend college. We have had a shift in our student population towards more low-income families and our SPED and 504 (students who fall under Section 504 of the Rehabilitation Act of 1973 that protects students with disabilities) populations have greatly increased. This has allowed us to shift our focus to helping all students reach proficiency while still maintaining an appropriate level of rigor for the whole student population.

My project focused on improving engagement, data literacy and conceptual understanding through the use of active learning strategies and contextual data analysis. Before starting this project, I noticed that the students at our school did not excel in the data interpretation portion on their math or science standardized assessments. When students were asked questions either on an assessment or verbally they often would respond with simple answers without being able to give justification to their claims. I was looking for a way to boost not only their scores but their overall skills so they have the tools they need to function in a highly technological and visual society. The majority of my teaching is done through guided note taking with several review activities. While my class is primarily hands on, I was also looking for a way to increase student engagement and ownership within the classroom.

Through my research I wanted to find out if contextual data analysis increased student motivation and engagement with data. By giving meaning to the numbers students work with, students may be more interested in analyzing what this data means. I also hoped that by increasing how much students work with meaningful numbers, these students would be more able to interpret any data set. In addition to this interest in data analysis, I also wanted to investigate if active learning could reinforce the qualitative concepts covered in Earth Science class. I believe that students being active learners is important, but creating engaging lessons is time consuming and must be scaffolded. Therefore, I wanted to understand if using vocabulary in the proper context extended the time it takes for students to learn the material. It was possible that the length of units would need to be adjusted in order to ensure student mastery through contextual and active learning strategies. These questions were answered through the use of a pre-and post-tests on interpreting data and concepts as well as through formative assessments, summative assessments and focus groups.

My primary focus was discovering how active learning strategies with a focus on contextualized data analysis, affected student data literacy and conceptual understanding. The sub-questions explored this focus further. *does contextual data analysis affect student engagement? How does active learning and contextualized information reinforce conceptual understanding? How does active learning and contextualized information* *affect student data interpretation skills? How will active learning strategies affect the length of my units?*

CONCEPTUAL FRAMEWORK

The world of today and the world students will rule tomorrow is becoming more and more scientific. People are surrounded by information, science and technology but few people, including major business, political and educational leaders, are truly aware of how to navigate and interpret such a society (Steen, 1991, p. 12). There are two areas in science teaching that can be improved to help students become more successful in any science class and hopefully in society. Through active learning and contextualization of data students will become more motivated, increase their abilities to interpret data, gain a contextual understanding of science concepts and be better prepared for future challenges.

Active Learning

Many traditional classrooms involve teachers being the prime facilitators of knowledge where the teacher talks while the students take notes or listen. The goal of active learning is to get students engaged and to help give students responsibility and ownership of what is being covered in class. Active learning is described in the Greenwood Dictionary of Education as:

> The process of having students engage in some activity that forces them to reflect upon ideas and upon how they are using those ideas. Requiring students to regularly assess their own degree of understanding and skill at handling concepts or problems in a particular discipline. The attainment of knowledge by participating or contributing. The process of keeping students mentally, and often physically, active in their learning through activities that involve them in gathering information, thinking and problem solving (Collins and O'Brien, 2003, p. 5).

Edwards (2015) promotes the use of active learning strategies to engage students intellectually, socially and physically to increase retention through direct experience with content (p. 26). A study done by Richmond and Striley (1996) looked into the social aspect of active learning where tenth grade students worked in groups of four to investigate real life problems in their science class. At the beginning of the year the students had few skills in experimental design and justification of ideas. However, the researchers found that by working in groups the students developed skills in argumentation and the formulation of logical, evidence based conclusions. Richmond and Striley concluded that the conceptual and social dimensions of the class were dependent upon each other in order to achieve the best results (p. 843).

The use of active learning can improve student engagement and increase testing scores while also lowering failure rates. A study conducted by Freeman et al. (2014) showed in undergraduate courses active learning increased test performance by half a letter grade while failure rates were raised up to 55% when lecturing alone was used (p. 8410). Stohr-Hunt (1996) found that students who participated in hands-on activities every day or at least once a week scored significantly higher in science sections on standardized tests (p. 105). Students benefit from experiencing information. Whether it is being involved intellectually, socially, physically or a combination of the three, students are more engaged, students take ownership of their learning, students use high level thinking skills, students are more likely to discover and create based on what they are learning and students are more likely to become lifelong learners (Edwards 2015, p. 28).

Contextual Learning

Having students participate in activities is a great way to increase student engagement and motivation. However, when students participate in work that they cannot connect with or relate to it can hold back these benefits. Many science classrooms today involve students passively learning science facts and concepts without being able to understand how they work in real life. Psychologists agree that cognition coexists with context and in order to learn something a context must be given for a student to relate to (Klassen, 2006). Klassen proposes a definition for context as, “The entities that connect to or surround a focal entity and contribute to the meaningfulness of the whole.” Going further he states, “Meaningfulness then arises out of factors like familiarity, social interaction, activity, reflection, logical relation, emotional response, and so on” (p. 34-35). In order to increase cognitive understanding of what is being taught teachers need to provide a context that promotes the creation of meaning for the student.

Contextualization of content is suggested to increase student retention of knowledge and student motivation. Rivet and Krajcik (2007) conducted a study in an urban middle school in Detroit where they found a strong correlation between students finding meaning with the content (contextualizing the information) and their achievement in the unit. Pre-test to post-test gains were higher for students who made attempts to relate to the data as well as performance on student created work. Another study completed by Ellwein et al. (2014) involved ten college professors using an online module, *Biology of Climate Change*, to provide rich context and data to their students so they could observe how it affects student engagement and motivation. The researchers concluded that student engagement improved and was largely due to the contextualized delivery of material and access to data that students could manipulate themselves. While this study was intended to investigate student engagement, many teachers claimed an improvement in student content knowledge (p. 585). Both studies gave students context and helped improve motivation and learning achievements.

Rivet and Krajcik (2007) focused more on qualitative concepts while Ellwein et al. (2014) included quantitative data to reinforce the qualitative concepts they were teaching. To help students observe qualitative concepts in real life teachers have attempted to provide students with context rich data. Lee and Bulter (2003) had sixth grade inner city students use an authentic Kids as Global Scientists program allowing students to use real-time data to make forecasts. The study found that students were able to make predictions that agreed with actual weather data, took more meteorological entities into consideration when making a forecast, increase the scientific knowledge use and identify relationships between meteorological concepts (p. 943-944). In addition to teaching content through data, several teachers are reinforcing data interpretation skills through content. In an attempt to provide authentic contextual learning in middle school classrooms Tabletop, a prototype data analysis software package and training videos were given to a school and used in various middle school classrooms. The teacher found that the Tabletop program helped students to become more engaged in answering minor and major questions and stimulated conversations on qualitative and quantitative data (Hancock, Kaput and Goldsmith, 1992, p. 361-362). These researchers found that the best way to improve data interpretation for their students was to scaffold the information and use data in context. Again, by giving students data that is meaningful or in context it will improve the connections between concepts already known and being learned. In science numbers can be powerful, but students need to learn how to interpret what the numbers or graphs that they are looking at mean.

Preparing for the Future

Miller (1998) conducted a study interpreting the survey responses from Americans and Europeans about scientific literacy. The results suggested that in 1995 three out of four adults in Europe and the United States would be unable to read or understand news or other information that utilized basic scientific constructs such as DNA, molecules or radiation (p. 213). Since 1995 our society has had a huge increase in the amount of information that is available. Students should be prepared to be able to interpret various types of scientific data. Designing experiments and interpreting evidence is becoming more of a priority in the NGSS. Quellmalz et al (2013) predicts that assessments will start becoming more active and interactive rather than static in an attempt to measure complex learning strategies like the application of concepts in context rather than just memorizing facts (p. 1111-1112). These Next-Generation assessments will require students to be able to collect, engage with and analyze data. Smith et al. (2014) conducted a study where students participated in the use of an online module that gave students access to authentic contextual data. The researchers found that using the module allows an average gain of 25% from the pre-test to the post-test. Teachers from the study shared in a survey that the module helped improve student ability to describe data and distributions in addition to creating evidence based arguments (p. 58).

Edward Mooney (2002) agrees that quantitative analysis needs to play a larger role in middle school in order to prepare our students for their futures. "Over 70% of the workforce in the United States deals with quantitative information on a daily basis… Inability to make use of quantitative information can hinder a person from being a productive employee, student, consumer or citizen in today's society" (p. 23). A recent study done by Morris et al. (2015) states that using data as evidence to support interpretations of phenomena is a vital goal of science education. The author goes on to say that if teachers involve more data interpretation and manipulation of that data to help challenge misconceptions and support ideas, student understanding the role of data in science would likely increase. Students need to learn how to interpret and manipulate data in order to be successful on future exams that measure how prepared students are for the real world.

Conclusion

Students today have access to a great deal of information and need to know how to interpret it. These students will need the skills necessary to be functioning citizens who can make informed and calculated decisions on civic matters in our democratic society. The analysis of the research indicates that active learning and contextualized learning strategies have positive impacts on students' abilities to interpret qualitative and quantitative information. By exposing students to more data in a given context that they can actively engage with, students will gain the skills they need to pass future assessments, major and minor, and be productive members of society. By emphasizing active learning, students will get to be involved in their own learning and grapple with concepts. By teaching through context, students will be able to find the meaning in what they are learning and make cognitive connections that promote long-term learning. By promoting more data analysis, students will gain the skills they need to be able to make evidence based conclusions, understand qualitative concepts and reflect on the information that is in front of them.

> “Simple interactive data visualization tools, combined with context about people and place, made the data more compelling, easy to understand, and more fun to explore. This sense of ‘play’ seemed to help students feel more comfortable and familiar with the data, improving their ability and willingness to ask scientific questions about the data” (Ellwein et al., 2014, p. 585)

This action research project incorporated active learning and contextual learning strategies with an emphasis on contextual data analysis in an attempt to improve student engagement, data literacy and conceptual understanding. I investigated if contextual data analysis helped reinforce the qualitative concepts that we learn in eighth grade Earth Science in addition to strengthening students’ overall ability to interpret any form of data.

METHODOLOGY

The treatment for this study includes the addition of contextual data analysis activities that allow students to manipulate data and information physically and mentally. The focus of this treatment is to help increase student motivation and engagement, data literacy and conceptual understanding. By having students more actively involved in class and with the material, the goal was to measure if engagement, data literacy skills and conceptual understanding would improve compared to my traditional style of teaching without adding too much teacher preparation.

Participants

The participants of this study are eighth grade Earth Science students at Twin Cities Academy in St. Paul, MN. These students come from various cultural and socioeconomic backgrounds and various experiences in science for the elementary grades. There are 98 students total between the four sections of eighth grade that participated. There were four sections of students, two receiving traditional methods and two sections receiving intervention units. Two sections were kept as a control group so I could have something to compare my treatment group to. My control group consists of my first two hours of the day with a total of 47 students. My treatment group consists of my fourth and fifth hour sections also with a total of 47 students. All students were made aware that their participation was entirely voluntary and agreed to participate in the study. 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 (Appendix B).

Intervention

For my traditional style classes, I focused on lecturing and basic activities to teach my students about the weather and atmosphere. Notes were given in a guided format where students could fill in the blank, draw pictures and write definitions of terms from a presentation. There were a few hands-on activities where the students would review or discuss information with the students around them, but the emphasis of the discussion was review of qualitative information only. Students were graded primarily on content knowledge and application of that knowledge to new scenarios.

For my intervention classes I had students gain information about the weather and atmosphere through contextualized active learning strategies like labs, videos and activities. The activities that accompanied lessons allowed students to observe data and discuss with their partners what conclusions could be made. The labs often included background information where students would be exposed to language within the proper context and the students would need to complete and analyze the data in the lab applying the language accurately and appropriately. An example of a background, prediction, analysis and conclusion sections for a lab can be found in Appendix A. The goal of my intervention unit was to give students the opportunity to challenge their prior beliefs and use data to develop evidence based conclusions. Students were encouraged and graded on their ability to interpret the data and apply their observations and inferences of the data to new situations related to the content that we learned in class.

Data Collection

There are several ways that I collected data based on the literature that I reviewed. Several studies included student surveys (Ellwein et al. 2014, Smith et al. 2014, Hammond. 2012, Heller 2015, Hart et al. 2000 and Freeman et al. 2014) where students ranked how well they were engaged or motivated throughout the units. I did this anonymously to get the students' true opinions about how they felt about a unit. Lovelace and Brickman (2013) explain how Likert scales can be used to find the student's real thoughts on something in class. The authors explain further that due to the ordinal data collected from Likert scales nonparametric tests would be best for this data. Choosing the right test depended on the distribution of results, sample size and more.

Hancock, Kaput and Goldsmith (1992) used several mini-assessments while using Tabletop data analysis to check on student ability to interpret various data sets. I thought this was a great idea and use of formative assessments. I regularly use formative assessments to guide my pacing in class. Using mini, formative assessments was critical in determining how the intervention affected the pacing of my units. Conversely, several studies used summative assessments with both student-created products and post-tests (Rivet and Krajcik 2007, Turner and Rios 2008, Hammond 2012, Lee and Bulter 2003, Heller 2015, Hancock et al., 1992 and Hart et al., 2000). These assessments measured student achievement through multiple modes, which allowed for students to be successful in different ways. I administered a pre-and post-test to my students and assessed the scores using a normalized gain. Not all students are skilled test takers, so allowing for labs and worksheets to be another measurement of success helps all students to demonstrate growth. Multiple assessments helped track student progress. Additionally, a large group project at the end of the intervention created another opportunity for students to demonstrate the knowledge they gained.

Almost all of the studies I reviewed included interviews with students (Miller 1998, Rivet and Krajcik 2007, Ellwein et al. 2014, Quellmalz et al. 2013, Hammond 2012, Heller 2015, Hancock et al.1992 and Hart et al. 2000). Interviews can help teachers understand the thought process of students. Rivet and Krajcik (2007) selected six students based on average scores, attendance and openness to interview and track. I had close to 100 students participating in this project; therefore, I chose to use a focus group. In this focus group, I assessed student ability to interpret data and growth. This focus group also provided a deeper understanding on how the students perceived their own growth and learning.

Table 1
Triangulation Matrix

Focus Question: How can active learning strategies with a focus on contextualized data analysis be used to help improve middle school student data literacy and conceptual understanding?			
Subquestions	Data Source		
Subquestion 1: How does contextual data analysis affect student engagement?	Pre-Survey	Focus Group Discussions	Post-Survey
Subquestion 2: How does active learning and contextualized information reinforce conceptual understanding?	Formative Assessments	Discussions Observations	Group Project and Post-test (summative assessments)
Subquestion 3: How does active learning and contextualized information affect student data interpretation skills?	Pre- and post-data literacy assessments	Discussions Observations	Formative Assessments
Subquestion 4: How will active learning strategies affect the length of my units?	Teacher Journal	Focus Group Discussions	Formative Assessments

Timeline

Both the traditional and intervention units lasted for eight weeks. The weather and atmosphere unit is the largest unit that we cover in eighth grade Earth Science and involves a large end of unit project. The data collection portion of this action research project started January 30, 2017, when quarter three began at our school and concluded on March 24, 2017. Data was interpreted as the project took place, which allowed for appropriate pacing and to check for understanding. The majority of deep data analysis occurred after the data collection period ended allowing appropriate time to interpret the trends and patterns in the data.

DATA AND ANALYSIS

The weather and atmosphere unit lasted approximately eight weeks. Throughout this time period I collected data via surveys, formative assessments, summative assessments and a focus group discussion. In total, 47 students participated in the control group and 47 students participated in the treatment group. The data helped me process the strengths and weaknesses of teaching through contextualized active learning strategies.

Student Engagement

The first question I investigated was, “How does contextual data analysis affect student engagement?” On the first day of the unit my students took an the Student Engagement Survey (Appendix C) to assess how involved students felt in the classroom before any treatment. Engagement is a vague term that many students have a hard time defining. As a result, instead of asking students who engaged they are in class, I described engagement using ten different questions and a Likert scale. This survey was administered again at the end of the treatment period. The results from the pre-survey (at the beginning of the treatment) and post-survey (at the end of the treatment) for both groups can be found in Figure 1 and Table 2.

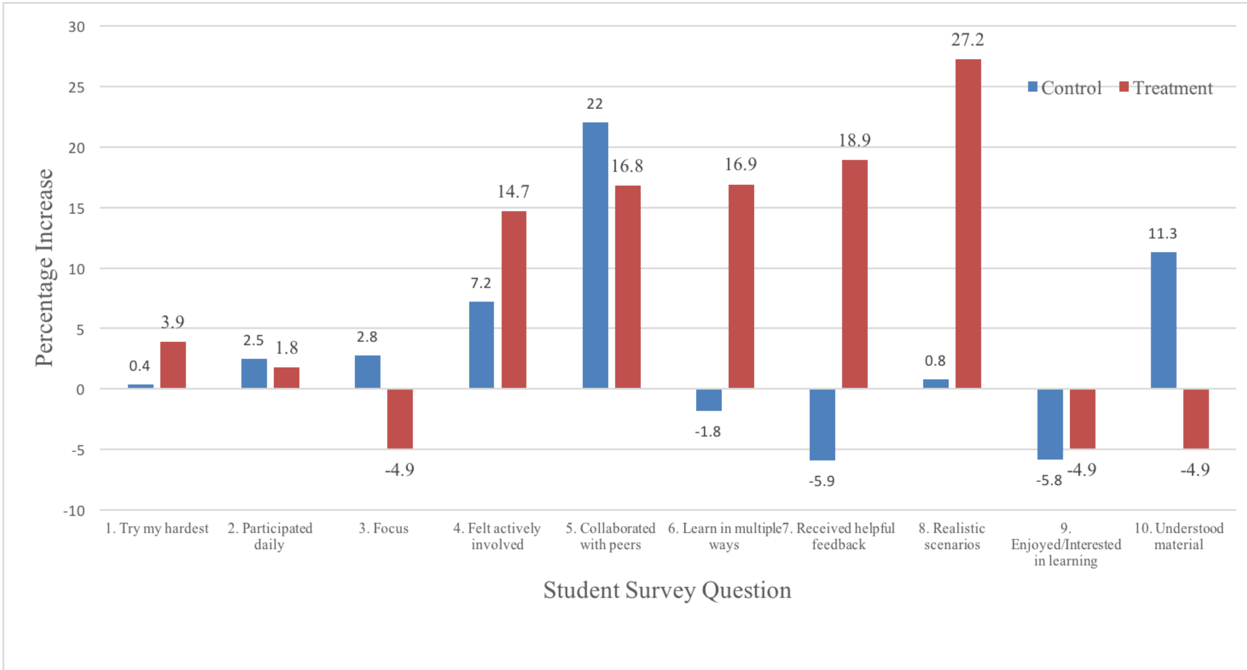


Figure 1. Student Engagement Survey Data: pre- to post-survey growth of positive responses, (Control *n*=45, Treatment *n* = 46)

Table 2

Student Survey Data (Control n=45, Treatment n = 46)

Student Survey Question	Control Pre-Survey				Control Post-Survey				Treatment Pre-Survey				Treatment Post-Survey		
	% Positive	% Negative	% Neutral		% Positive	% Negative	% Neutral		% Positive	% Negative	% Neutral		% Positive	% Negative	% Neutral
1. In the last two weeks I have tried my hardest to complete all homework.	78	2	20		79	2	19		81	9	10		85	7	8
2. In the last two weeks I have participated in class daily in some way.	83	2	15		85	0	15		83	0	17		85	2	13
3. In the last two weeks I have been able to focus in class.	72	7	21		75	0	25		75	0	25		70	4	26

4. In the last two weeks I have felt actively involved in class.	61	13	26		68	2	30		72	9	19		87	4	9
5. In the last two weeks I have collaborated with my peers to accomplish something in class.	67	7	26		89	0	11		75	6	19		92	2	6
6. In the last two weeks information was presented in multiple ways.	85	7	8		83	0	17		81	4	15		98	0	2
7. In the last two weeks I have received feedback in class that helps my learning.	80	2	18		75	2	23		68	6	26		87	0	13
8. In the last two weeks I have applied what we learned in class to a realistic scenario.	61	2	37		62	2	36		49	21	30		76	9	15
9. In the last two weeks I have enjoyed/been interested in the way we learned.	70	9	21		64	4	32		77	4	19		72	4	24
10. In the last two weeks I feel like I have understood the material we covered in class.	72	7	21		83	2	15		77	2	21		72	2	26

At the beginning of the treatment, during the pre-survey, the control and treatment groups had similar results for the ten question survey. The students rated “participation” (question 2) and “learning in multiple ways” (question 6) as their highest categories with percentage of positive results being 83% for my control classes and 81% for my treatment classes. The lowest scoring category for both classes was” applying what we are learning to a realistic scenario” (question 8). For “realistic application” 61% of my control students gave positive responses, while my treatment group only had 49% positive responses. Of the ten questions, only two questions had differences greater than

8% between the control and treatment classes. “Realistic application” and “receiving helpful feedback” (question 7) had 80% of the control group responding positively and only 68% of the treatment group responding positively.

The post-treatment surveys were compared to the pre treatment surveys after the completion of the unit. I used the Chi-square test of independence to see if the results for control group or treated group were significant. For the control group, between the pre- and the post-surveys, there was significant increase (p=.0232) in students who agreed that they collaborated with their peers to accomplish something in class. The treatment group saw significant growth in application of what we are learning to realistic scenarios (p=.0250) and in presentation of information in multiple ways (p=.0290) between the pre- and the post-survey. Another category that saw sizeable growth (p=.0529) for the treatment group was the feeling that they received feedback that helps their learning.

When comparing the pre- and post-surveys, I was looking for trends to indicate growth of more than 10%. This would equate to five students joining the positive responses group. If I consider this as positive growth, the control group had growth in two categories compared to the treatment group which had growth in five categories. The areas of growth for the control group were collaborating with peers (question5) and confidence in understanding the material (question 10). The areas of growth for the treatment group were active involvement in class (question4), collaborating with peers, multiple ways of learning, receiving feedback and application of information to realistic scenarios. For both groups, there were three categories that saw a decrease in positive results, none of which were statistically significant.

The focus group discussion helped to explain some of the growth in the treatment group as well as the small decrease in focus (question 3), enjoyment (question 9) and understanding. The students from the focus group were from the treatment group, because I wanted to gain understanding as to what they thought of the assignments that were specifically designed for the treatment group. These assignments included a lab on layers of the atmosphere, a solar declination lab, current conditions investigation and the weather report summative assessment. The focus group students came from a variety of backgrounds and had grades in my class ranging from A's to C's, which represented the typical demographic of my students. Focus group questions can be found in Appendix D. While conducting the focus group discussion I recorded the session and took notes of key points and ideas shared by several of the students. Many of the students agreed that they preferred doing labs and activities with information built into the background section. They all found this more challenging but explained that the background section really helped them interpret the data and helped them find meaning in what they were trying to accomplish. For instance, on student stated, "The questions were more challenging and it made you think outside of the box more; I like that instead of just learning something and exactly what it is…and how to apply it to a scenario. I really like that." Another student said, "It forces you to know it instead of you writing on the board telling us how to because then I don't really actually learn it." The students in the focus group who usually are in the C range of grades wished there was more time for formal notes like we did the rest of the year. However, they also said that it should accompany the labs and activities rather than replace them. The whole group agreed that having access to formal notes in addition to the contextualized information in the background sections would help. By having these extra resources the students felt they would have something to turn to when they are seeking clarity on topics.

In the focus group discussions, there were a few students who mentioned that working in assigned group was sometimes more productive and at other times less productive. The students had mixed views on group productivity. I think that is what led to a decrease in focus for my treatment group. My control groups received formal notes almost daily. Therefore, there was always a part of the class that required students to focus on content in order to keep up and have a clear structure of class. My treatment groups had multiple days in a row where we would check-in quickly before they worked in groups on their labs. Students said this could lead to people "checking out" or losing their attention and focus for the day. The whole group agreed with one student's statement, "I like partners better than working in groups, it's easier to divvy up the work… and in bigger groups at least half the group doesn't do anything." When the focus group students were directly asked if they felt engaged, all of them said that they felt engaged to varying degrees. Almost all concluded that the content was interesting and they enjoyed the challenging labs and content. Several stated that they were less engaged when we had whole class discussions compared to small group discussions. When asked how this unit compares to past units, all students agreed that is was, "Better. More fun."

Between the surveys and the focus group discussion, I received some great feedback as to how engaged my students were. My own observations confirmed the student feedback. For the group discussion observations, I took notes on the quality of responses that students were giving when responding to question or presenting information to a group. Group discussions were classified as any time when a student presented to multiple people so I was able to see progress in groups as small as two and in whole-class discussions. I noticed that my treatment groups seemed more active in class and asked more questions to seek understanding rather than to just ask for help. Because I spent less time formally giving notes I was more available oup to check for understanding while students were completing labs and activities with their peers. I witnessed great conversations on how to complete the labs and more importantly how to interpret the results. There were some great arguments that I had to eventually declare a winner to, but ultimately students were engaged in the content. In my control classes, I was able to interact with groups but there was less time to do this. I noticed that the conversations were often more about procedures rather than conceptual understanding. My control classes were quick to ask for assistance rather than seeking understanding for themselves. That being said, all of my classes have mostly positive attitudes towards our science class which hopefully continues as they enter high school.

Conceptual Understanding

As a science teacher, conceptual understanding is key in order for my students to succeed on summative and state assessments. The second question I investigated was "How does active learning and contextualized information reinforce conceptual understanding?" The formative assessments that we completed as labs in the treatment group were more challenging than the assignments that I gave my control group. The control group received the assignments that I had been giving for the last three years, which had several advantages. The students were given information as guided notes, which is what they were used to compared to the rest of the year. The assignments were designed to review the material in the notes rather than to synthesize new explanations. This helped students score high on these assignments without assistance from group discussions. My confidence and comfort level with these assignments and teaching methods also helped because I could anticipate where students would struggle and what I would need to emphasize to help students find understanding.

The students in the treatment group had to find information for their labs in the background section. This was not necessarily more difficult, but because this was a new way of doing things in class, it added an extra factor of difficulty for many students because students did not have a note sheet to reference. Also, questions were designed to help students draw conclusions based on the data from the lab. The questions were intentionally challenging to help encourage students to have more meaningful conversations about how to interpret the data and apply it to new scenarios. The student focus group agreed that students found the lack of notes and questions challenging.

As we advanced through the quarter, students continued to struggle with the questions that accompanied each lab. However, they were more willing to collaborate and find the answer rather than complain about the difficulty and give up. Many students started explaining their answers rather than using short statements to answer questions. The first assignment on the layers of the atmosphere required students to answer questions in their packets with their partners. For this assignment, I was pretty lenient with grading the explanations. We also reviewed every answer together so students would understand what kind of detail was required for their responses. On the first assignment, the average score was 89% for the students who completed the assignment. After the assignment, I started grading students on their ability to justify their responses with evidence from the lab or activity. We completed a greenhouse gas simulation, a solar declination lab, a current conditions simulator with real time data. Between all of these assignments, the average score was 91%. While this is not a substantial increase quantitatively, the assignments were more difficult and the quality of responses improved. I took this as a great indication that students were becoming more confident to form conclusions about the concepts covered in class as well as an increase in their comfort levels when it comes to challenging themselves.

The group discussions in all classes were interesting. My control groups often focused on asking questions related to strange hypothetical situations. I would have to explain answers to these situations rather than applying information to more realistic scenarios. While these discussions were great for student engagement, they did not always lead to greater conceptual understanding. There was also little accountability for the information that was shared. When the opportunity arose, I would ask for student volunteers to try to explain answers before I would lead them to the answer, but there were rarely volunteers with accurate explanations. My control classes had less opportunity for small group discussions simply because more time was allotted for notes making so it was harder to get an idea of how each student was progressing.

My treatment classes had the advantage of having questions on their assignments that called for higher order thinking skills and applying information to new scenarios. Because these students didn't have the original notes given as a class, they were more attentive and interested in making sure that their answers were correct. This accountability helped increase student involvement in discussions because they had to justify their responses to questions. One student stated, "I think it's a good challenge as long as you pay attention." Just like the written responses students were hesitant at first about sharing their answers but throughout the unit gained confidence in their answers. The pride of coming to an accurate conclusion outweighed the fear of coming to an inaccurate one for most students. However, a small percentage of students were unwilling to give answers to the whole group. Because I had more time with my treatment groups during work time I was able to circulate and have small group discussions to gain insight as to how my less vocal students were progressing. Small group discussions were much better for me to get a picture of how all students were doing. It also helped me have a plan for who to call on in whole-class discussions to help build confidence for some and make sure that we got to the correct answers.

The final way that I collected data on conceptual understanding was through summative assessments. The same unit test was given to all of my classes. The unit test was divided into six different sections based on the six state standards that we covered in the unit. By comparing overall scores and standard scores I was able to compare classes. I used a t-test to compare the overall scores. There was no significance in the difference between the groups ($p=.42$). The average for my control classes was 77.5% while my treatment classes had an average of 80.6%. Although the difference was found to be insignificant, there was a difference even though I was teaching in a way that was new to both the students and me. The results from the unit test can be found in figure 2.

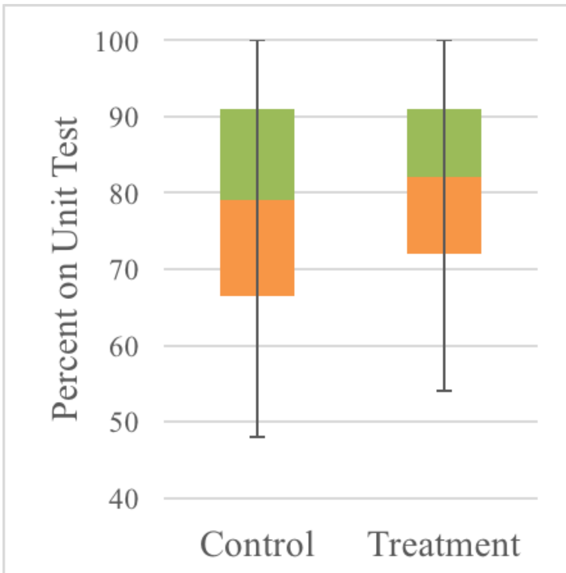


Figure 2. Unit Test data by standard.

The graph shows that although there is a lot of overlap in the results, the treatment group has a smaller interquartile range and a higher median suggesting that the students scored more consistently higher than the control group. The top 25% of the scores for both treatment and control groups were about the same and represents students who most often receive A's in my class. The middle 50% of the scores for the treatment group outperformed the middle 50% of the control group. The bottom 25% of the treatment group is also more elevated than the control group meaning the lowest testers from the treatment group outperformed the lowest testers from the control group.

In Table 3 and Figure 3 each standard is identified. There was still no significant comparison when completing a t-test but the results show that the treatment group outperformed the control group in every category except the water cycle. This could be because the control group completed individual projects on the water cycle compared to the treatment group which ran short on time during this part of the unit and did a group think pair share project instead.

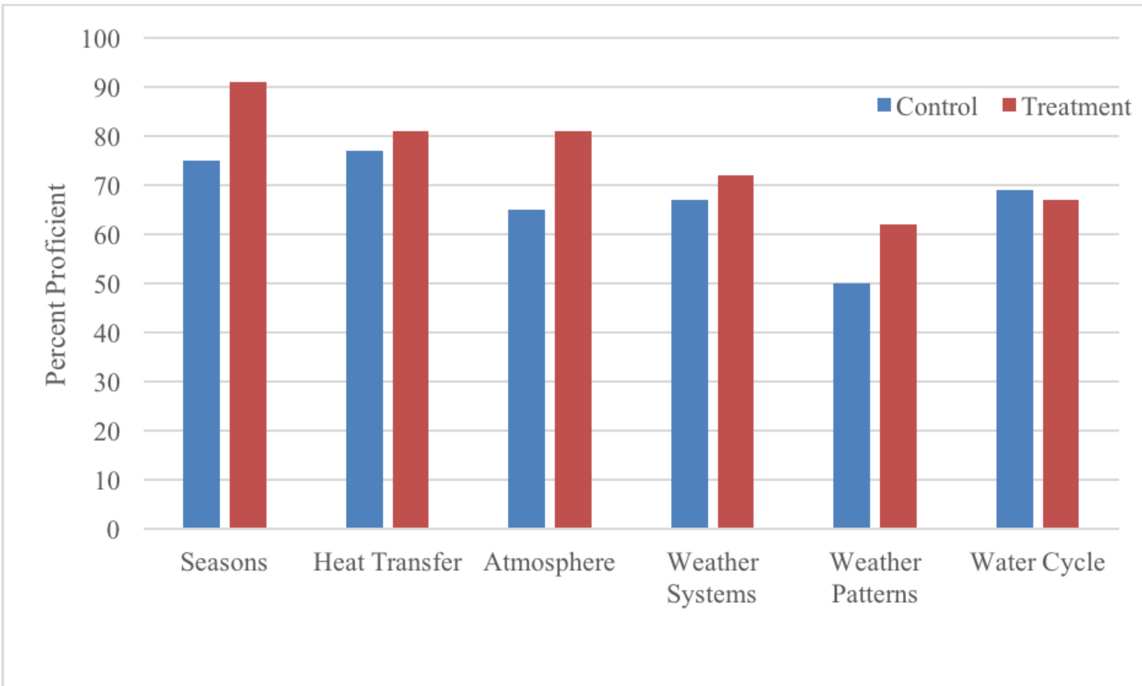


Figure 3. Unit Test data by standard.

Table 3
Unit Test Data by Standard

State Standard	Percentage of Students Passed Control	Percentage of Students Passed Intervention
8.3.2.1.1 – Explain how the combination of the Earth's tilted axis and revolution around the sun causes the progression of seasons.	75%	91%
8.3.2.1.3 – Explain how the heating of the Earth's surface and atmosphere by the sun drives convection within the atmosphere and hydrosphere producing winds, ocean currents and water cycle, as well as influencing the global climate.	77%	81%
8.3.2.2.1 – Describe how the composition and structure of the Earth's atmosphere affects energy absorption, climate and the distribution of particulates and gases.	65%	81%
8.3.2.2.2 – Analyze changes in wind direction, temperature, humidity and air pressure and relate them to fronts and pressure systems.	67%	72%
8.3.2.2.3 – Relate global weather patterns to patterns in regional and local weather.	50%	62%
8.3.2.3.2 – Describe how the water cycle distributes materials and purifies water.	69%	67%

In addition to the unit test, students worked in groups of four to create a weather report. The requirements of the project included students creating a national map of the United States and regional map of the region of their choosing. Once students had created maps with fronts, air masses and current conditions they would have to give an actual weather report in two minutes summarizing what the forecast would be for the nation and more thoroughly for a specific region. The control and treatment classes had the same assignment with the treatment class having an additional piece of adding weather station data to ten different cities across the nation. The student feedback was fantastic for each class and almost all students reflected in an assignment that it was their favorite way to show understanding.

Each group presented to the whole class for the weather report and was graded on a scale of one to three where one represented data being mentioned a few times but not in a meaningful or accurate way, two represented data being used to support more than half of the descriptions or predictions in a meaningful way and three represented data be used to back up every description or prediction in a meaningful way. I graded each group on a variety of weather topics and their ability to support their answers using qualitative and quantitative data. The control classes had an average of 1.958 for use of qualitative data and 1.375 for quantitative data. The treatment classes average 1.917 for qualitative data and 1.750 for quantitative data. The treatment classes outperformed the control classes in quantitative data which was not surprising considering that we had focused on the use of quantitative data to support conclusions throughout the unit. I was slightly surprised to see the control classes outperform the treatment classes qualitatively, even if only by a little. This could partially be attributed to the fact that the treatment groups were focused more on weather station data and accuracy with numbers rather than emphasizing specific vocabulary. The focus group discussion later confirmed this thought.

The students from the focused group said that learning primarily from the labs and activities with the contextualized data was challenging but in the end made the information more meaningful and easier to recall. One student stated, "I feel like it takes less studying from me. It's just like it's in my head. When it comes to the test it just pops in." The results from the summative assessments reflect this and I am interested to see how scaffolding these tactics throughout the year rather than just having students jumping into this style of learning would affect the outcome. The summative assessments did not show significant differences but there were differences that supported conceptual understanding in the test group.

Data Literacy

Through my action research project, I investigated how active learning and contextualized information affected student data interpretation skills. One of the best ways that I assessed if my treatment classes outperformed my control classes was to give a pre- and post-test assessing data interpretation skills. I created the Data Literacy Test (Appendix E) that assessed basic data interpretation skills for data tables and graphs that would be helpful in future classes and in life in genera. The results from the pre-and post-test are shown in Table 4.

Table 4
Data Literacy Test Data

Group	Pre-Test Percentage	Post-Test Percentage	Percentage Gain
Control	54.2%	65.4%	11.2%
Treated	56.5%	71.1%	14.6%

The results from the pre- and post-test show that the treatment group outperformed the control group. Not only did the treatment group outperform the control group, they also had a higher average gain than the control group. The normalized gain test showed that this was not a significant difference. The average normalized gain for the control group was 2.04 points while the treatment showed an average normalized gain of 2.41points (p=.47).

Despite the insignificance of the data for the pre-and post-test, when the information was presented in a box and whiskers plot there are some trends that would support more growth for the treatment group (Figure 5).

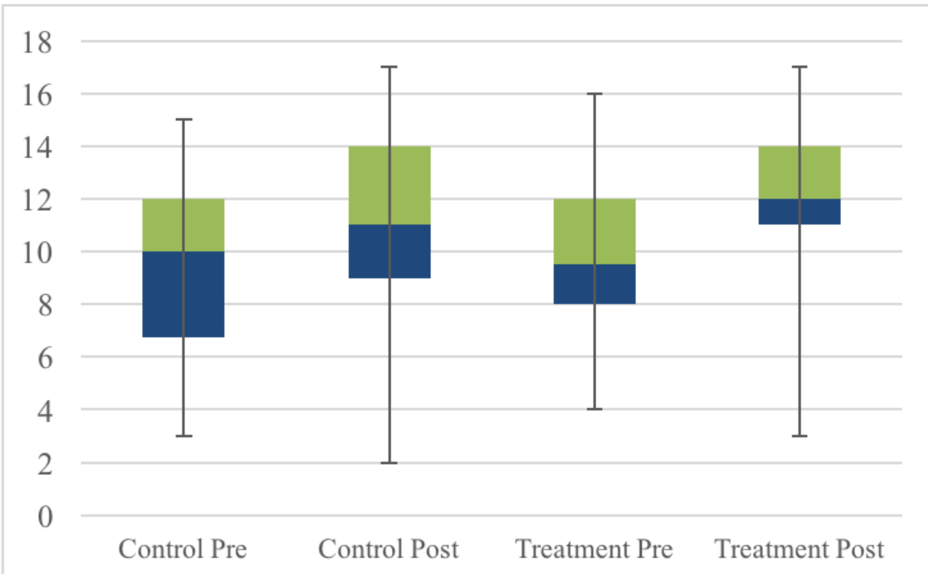


Figure 4. Data literacy pre and post assessment results.

In this figure the treatment group's post data literacy assessment showed a higher median, higher average and more consistent data which means that majority of the treatment students outperformed the majority of the control students. Student performance during group discussions and assessments that support the treatment group gained more data literacy skills than the control groups. Data was reviewed in all of my classes through group discussions with more emphasis being in my treatment groups. My control classes looked at basic atmospheric trends compared to the treatment classes that had actual data from weather balloons. When addressing the data, the control classes had little participation as a large group in discussing the data and what it meant. They were able to see the major trends but struggled with drawing conclusions about specific layers of the atmosphere from a simple graph. My treatment classes were asked more in-depth questions could be answered by using the graph and by using the extensive data table they had in their packets. Because we had more data in my treatment classes it made it easier to identify highs, lows and average temperatures in the different layers in addition to composition of the layers. Throughout the entire unit, the treatment classes had more thorough discussions that were often more student led than my control classes comparatively.

The formative assessments were great indicators as to how my treatment group progressed with their data interpretation skills. Because I was pushing for students to support answers with evidence, they improved at explaining this answers using any data that was provided. Many labs and activities included quantitative data but the current conditions assignment helped students link real time qualitative and quantitative data to explain how atmospheric conditions impact the weather at specific locations around the globe. The control classes also completed labs and activities where they gathered and interpreted data but not to the same extent.

Besides the summative assessments, there was only one assignment that involved data interpretation that was exactly the same for my control and treatment classes. The students completed an online simulation on greenhouse gases that had various questions asking them to interpret what they were seeing, manipulate variables and make comparisons to realistic scenarios. The assignment was scored out of 30 points. The control classes had an average score of 27.8 while the treatment classes had an average of 29.0 points. When a t-test was completed using the scores from this assignment the data was considered insignificant ($p=.0697$); however, there were some notable differences. I had more students from my control classes come in outside of class time in order to complete the assignment with me or another adult. I think this occurred partially due to a lack of data literacy skills and confidence, but also due to an unwillingness to collaborate with their peers on challenging assignments. I only had one student from my treatment classes come in for assistance on this assignment and that student had recently transferred to our school in the middle of the unit.

Length of Units

One major limiting factor in the classroom is time. Part of my investigation was to see how well active learning strategies affected the length of my units and if teaching through contextualized active learning strategies is a viable option with the given amount of time that I have with my students. I collected my own data in a journal, compared the time it took for my classes to complete formative assessments to gather data and heard from my focus group about their thoughts on time management in the classroom.

In past years my weather and atmosphere unit has been around six weeks long. I knew that my action research would extend the length of the unit just by adding days to complete pre- and post-tests and surveys. This year’s unit lasted eight weeks plus the two days required for the pre- and post-test and surveys. The length of the unit was extended due to a need to re-teach some topics and in order to accommodate the labs that were designed for my treatment classes. My control classes were given more time to work on homework in-class compared to the rest of the year to accommodate for the extra time that my treatment classes needed to complete their labs. I took notes on the fact that, "I was frustrated with the time lost due to slow work in the classroom." Reflecting back on this at the end of that week and at the end of the unit, I have come to the conclusion that even though time was "lost" due to processing in the classroom, I spent less time re-teaching concepts at the end of the unit for my treatment classes. Often if a student struggled with a question, I could remind them of a lab that we did and they would be able to find the answer on their own. For example, one student asked, "Ms. Berg, when did we ever learn what causes the seasons?" After looking at the student quizzically for a second I told them, "Remember the solar declination lab?" and then the students confidently shooed me away. I checked back in on that student to make sure they understood the material. Overall the unit was longer by about two weeks, but my treatment classes required less review than my control classes. I think this was a great sign of retention.

When I talked with the students in my focus group every single one of them said that they wanted more time for the labs. When asked about pacing in general, the students said that they enjoyed the fast pace that we move at because it keeps them engaged but the labs simply needed more time in order to process the data. One student stated, I like the pace that we are going at now. The big project we just did had way more stuff and I need more time to really get it." My observations confirmed this, but it was interesting hearing from the students how much the quick deadlines stressed them out in class when it came to labs and projects. When asked if they thought that they would be better at labs if we did them more often, they agreed. The students argued that it would be faster, but they still wanted time to discuss answers with their groups more deeply. More experience teaching the labs that I assigned will likely decrease the amount of time required, because I will be able to anticipate questions and places where students struggle. Using labs with contextualized information and data right away at the beginning of the year will allow me to scaffold and prepare my students for my high expectations.

INTERPRETATION AND CONCLUSION

The main question investigated was, “How can active learning strategies with a focus on contextualized data analysis be used to help improve middle school student data literacy and conceptual understanding?” The data collected throughout the project led to several discoveries with the most of important being that the contextualized data analysis lea to an increase in engagement and higher quality conceptual understanding.

There was growth in student engagement for the control and treatment groups but the treatment group saw more improvement and in several categories. The treatment group showed significant growth in collaboration with peers, application of information to realistic scenarios, presentation of information in multiple ways and in the feeling that they received feedback that helps their learning. These findings aligned with Ellwein et al. (2014) and Rivet and Krajcik (2007) who also found that contextualized learning increased engagement. The assignments that included contextualized information were designed to get students collaborating with their peers while looking at real data. This helped students connect with the information. Edwards (2015) found that students who are more engaged in class will also use higher level thinking skills and be willing to discover information. Through my observations I had similar findings in my classroom. After adjusting to the new way of learning students had richer conversations where they would formulate hypotheses, argue and make evidence based conclusions. The contextualization of information really pushed the students to find meaning and draw their own conclusions without me telling them what they should be taking away from the assignment.

The focus group discussion helped reveal that the students felt like they were engaged in many ways and liked the way they were learning. The students in the group agreed that the contextualized information was more challenging but almost all stated that they felt this helped them connect to and recall the information. Klassen (2006) found that context and cognition go hand in hand and based on my results I would agree. The contextualized information really helped the treatment group find the information more meaningful while the active learning strategies gave the students more memorable events to help students recall information for assessments and discussions.

The treatment group felt that they were learning in multiple ways which is likely due to the way that the assignments and activities were designed. All assignments involved data being presented but for every assignment data was presented in a different way. Students had to interpret massive data tables and graphs, create data tables and graphs and observe various types of computer simulations presenting real time data in some type of graphic map or picture. Lee and Bulter (2003) found that real time data helped with student data interpretation skills and lead to conceptual understanding. There was more growth in data interpretation skills for the treatment group and while this was not statistically significant the students in the treatment group did show similar results to that of Lee and Butler's study.

As the research project was taking place I could see the differences between my control and treatment classes and I was not surprised to see that many of the differences between the groups were statistically insignificant. I knew going into the project teaching something new would be a challenge to both my students and me and that there would be several improvements that would not necessarily be measureable given my present comfort with the way the control group was instructed. The unit test was originally designed for my usual instruction methods so it was interesting to see that the treatment group outperformed the control group in five of the six standards covered in this unit. I observed differences between the classes that are hard to quantify. Students made more evidence based conclusions, students made better evidence based conclusions, students had higher quality conversations with vocabulary from class and students enjoyed class more. Much of my research supported that contextualized data and active learning lead to high levels of engagement and conceptual understanding and my findings coincide with their findings in several ways.

VALUE

If I were to do this project again, I would make more frequent meetings for student focus groups. The feedback I received from the students was invaluable and opened my eyes to many things I had not considered. Students discussed with me how they like to learn and that challenges are preferred to an extent. I already differentiate my classes, but the interviews helped me identify more ways that I can differentiate in order to allow students to learn and discover at paces that help push them at appropriate levels.

Going into this project I knew that scaffolding is a big role in contextualized learning and that I didn't have time for much of it with my project. Next year I am going to incorporate more contextualized projects but we are going to start out with small changes so students do not panic with the increase in collaboration, independence and application of knowledge. I am also going to take advantage of this summer to design assignments that are contextualized in even more ways. I incorporated a fair amount of variety with my project but it will be nice to have more time to develop extensions to and differentiate assignments. In addition to this I also want to have students collecting their own data from the real world so they can continue to see the realistic application of what we are learning.

I found this action research project to be helpful in pushing me to keep striving for better teaching methods in my class that are data driven. I often try new things in my class but committing to a big change can be intimidating and if you are going to expend the time and energy you want to make sure it is productive before going all in. This study has helped confirm my desire to increase the amount of contextualized information I want expose my students to and has helped me find several resources for other improvements I want to make. In teaching it is so important to keep up with research and to teach your students in the best way possible but it can be difficult to know just how effective our teaching methods are. This action research project has shown me that collecting data and analyzing it appropriately is important to know if we are on the right track. After speaking with the administration at my school I am hoping to start a teacher symposium at my school so at the end of the year where teachers can show off any action research studies they do throughout the year and get compensated for their hard work.

REFERENCES CITED

Active Learning. (2011). In J. Collins & N. O'Brien (Eds.), *Greenwood Dictionary of education*. Westport, CT: Greenwood.

Edwards, S. (2015). Active Learning in the Middle Grades. *Middle School Journal,* 46(5), 26-32

Ellwein, A.L., Hartley, L.M., Donovan, S. and Billick, I. (2014) Using rich context and data exploration to improve engagement with climate data and data literacy: bringin a field station into the college classroom. *Journal of Geoscience Education* 62(4), 578-586.

Freeman, S., Eddy, S. L., McDonough M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M.P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy or Sciences of the United States of America,* 111(23*)*, 8410-8415.

Hammond, M. L., (2012). The implementation of mathematics journals in the science classroom to raise student achievement in science class. Retrieved from Montana State Online Library Scholarworks

Hancock, C., Kaput, J. J., Goldsmith, L. T. (1992). Authentic inquiry with data: critical barriers to classroom implementation. *Educational Psychologist,* 27(3), 337-364

Hart, C., Mulhall, P., Berry, A., Loughran, J.,& Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments?. *Journal of Research in Science Teaching,* 37(7), 655-675.

Heller, A. P. (2015). The impact of inquiry learning on students' ability to analyze data and draw conclusions. Retrieved from Montana State Online Library Scholarworks

Klassen, S. (2006). A theoretical framework for contextual science teaching. *Interchange* 37(1-2), 31-62.

Lee, H-S., Butler, N. (2003). Making authentic science accessible to students. *International Journal of Science Education,* 25(8), 923-948.

Lovelace, M. and Brickman, P. (2013). Best practices for measuring student's attitudes towards learning science. *CBE- Life Sciences Education,* 12, 606-617

Miller, J.D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science* 7(3), 203-223

Mooney, E.S. (2002). A framework for characterizing middle school students' statistical thinking. *Mathematical Thinking and Learning* 4(1) 23-63, DOI: 10.1207/ S15327833MTL0401_2

Morris, B.J., Masnick, A.M., Baker, K. & Junglen, A. (2015). An analysis of data activities and instructional supports in middle school science textbooks. *International Journal or Science Education* 37(16) 2708-2720 , DOI: 10.1080/09500693.2015.1101655

Quellmalz, E.S., Davenport, J.L., Timms, M.J., DeBoer, G.E., Jordan, K.A., Huang, C-W., Buckley, B.C. (2013). Next-Generation environments for assessing and promoting science learning. *Journal of Educational Psychology*, 105(4) 1100-1114.

Richmond, G. & Striley, J. (1996). Making meaning in classrooms: social processes in small-group discourse and scientific knowledge building. *Journal of Research in Science Teaching*, 30(8), 839-853.

Rivet, A. E. and Krajcik, J.S. (2007). Contextualizing instruction: leveraging students' prior knowledge and experiences to foster understanding of middle school. *Journal of Research in Science Teaching* 45(1), 79-100.

Smith, A., Molinaro, M., Lee, A., & Guzman-Alvarez, A. (2014). Thinking with data: students use authentic data to form evidence-based conclusions and think like a scientist. *The Science Teacher*, 81(8), 58.

Steen, L.A. (1991). Reaching for science: literacy. *Change*, 23(4), 10-19.

Stohr-Hunt, P.M (1996). An analysis of frequency of hands-on experience and science achievement. *Journal of Research in Science Teaching*, 33(1), 101-109.

Turner, M. J., Rios, J. M. (2008). Determining paths to success: preparing students for experimental design questions on standardized tests. *The American Biology Teacher*, 70(3), 140-152.

APPENDICES

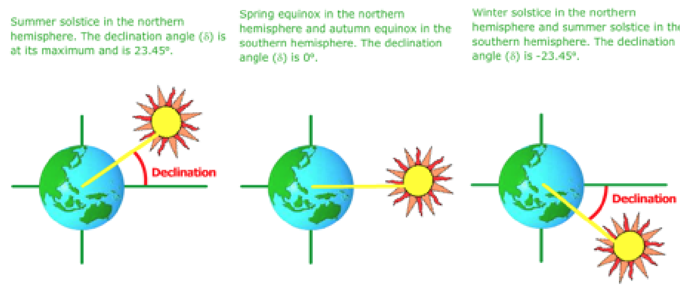
APPENDIX A

TREATMENT EXAMPLE

How the Sun's Declination Affects a City's Angle of Sunlight

In the last lab that you did you discovered that angle of light has an affect on temperature. We discussed the difference between direct and indirect light and how they influence temperatures. In today's lab you are going to explore how different places on the Earth are affected by the angles of the sun. Read the background section to learn about the terminology and lab set up you will be using today.

Background:
Recall from Geography class that a location's **latitude** corresponds with its distance from the equator. They are the lines on a map that look like rungs on a ladder. The higher the latitude the farther form the equator that location is.



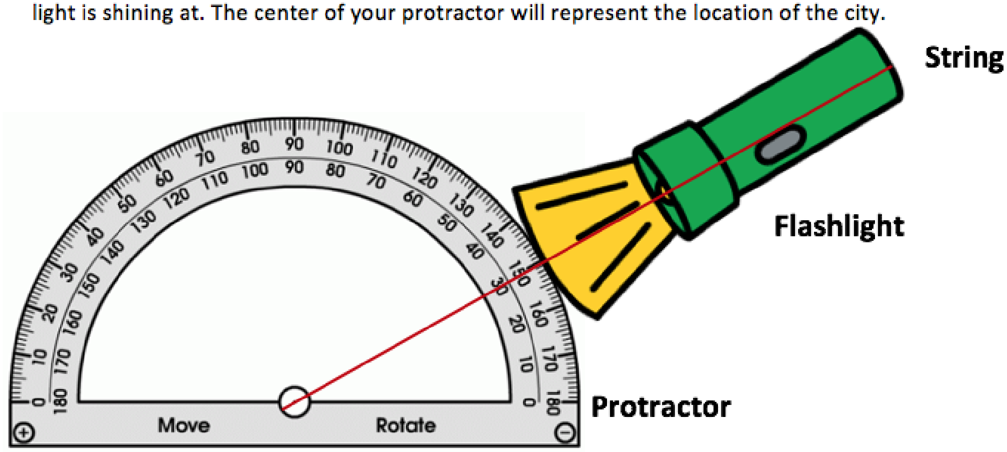
The **solar declination** is identified as a specific latitude where the sun's rays meet the Earth at a 90° angle at noon (most direct light possible). Throughout the year the solar declination moves across the Earth's surface allowing different places around the world to receive different angles of sunlight.

Recall from Math class that a protractor can help you measure the degree of a specific angle. In our last lab we looked at how temperature was affected between a tilted and flat surface, today we will be using protractors to simulate the sun shining at different angles throughout the year for different locations on Earth. To calculate the angle of sunlight shining on a specific place you can use the formula below:

$$\boxed{90° - \text{latitude} + \text{solar declination} = \text{solar angle}}$$

Noontime sun angles for any given latitude can be determined by subtracting the latitude from 90° and adding the solar declination. For example, Toronto, Ontario has a latitude of 44°N and on June 21st the solar declination is 23.26°. To calculate the solar angle you plug in the information you need. The equation is 90° - 44° + 23.26° for a solar angle of 69.5°.

For today's lab, once you have calculated the solar angle you will use a flashlight and protractor to simulate the different angle of sunlight a specific city gets throughout the year. The string will indicate what angle the light is shining at. The center of your protractor will represent the location of the city.



How Angle of Sunlight Affects Our Seasons

Now that you have the equation and information that you need, work with your partner to complete the various steps and analysis at the end of the lab. For this lab we will used a simplified version of the intensity equation to calculate light intensity. Because we will be using the same flashlight for each trial, we can assume that the smaller the surface area lit by the light, the more intense the light will be.

$$\text{Light Intensity} = \frac{Power}{surface\ area}$$

Question: How is the intensity of light affected by the solar angle?

Hypothesis: Write a hypothesis in "If…then…" form to answer the question above. Use the knowledge that you gained from the last lab.

____

____

Materials:

- Flashlight with string attached
- 4 pieces of paper
- Ruler
- Geography Textbook or laptop
- Protractor
- 4 different colored markers/pencils
- Calculator

Part I: Identifying Latitudes and Making Predictions

Use your Geography textbook or laptop to look up the latitudes for the following cities. After you write down the latitude, predict what day of the year each city will experience the most intense sunlight.

City	Latitude	Day of the year with most intense sunlight
Quito, Ecuador		
Miami, FL		
St. Paul, MN		
Barrow, AK		
Rio De Janeiro, Brazil		

Part II: Calculating the Solar Angle

Using the Table of the Declination of the Sun to find the solar declination on specific days throughout the year. Be sure to include whether the angle is positive or negative, this is important when calculating solar angle. Use the following equation to calculate solar angle. Leave the Surface Area column empty for now, we will come back to that for our analysis section

$$90° - \text{latitude} + \text{solar declination} = \text{solar angle}$$

A) Quito Ecuador

Date	Latitude	Solar Declination	Solar Angle	Surface Area
March 21st				
June 21st				
September 21st				
December 21st				

B) Miami, FL

Date	Latitude	Solar Declination	Solar Angle	Surface Area
March 21st				
June 21st				
September 21st				
December 21st				

C) St. Paul, MN

Date	Latitude	Solar Declination	Solar Angle	Surface Area
March 21st				
June 21st				
September 21st				
December 21st				

D) Barrow, AK

Date	Latitude	Solar Declination	Solar Angle	Surface Area
March 21st				
June 21st				
September 21st				
December 21st				

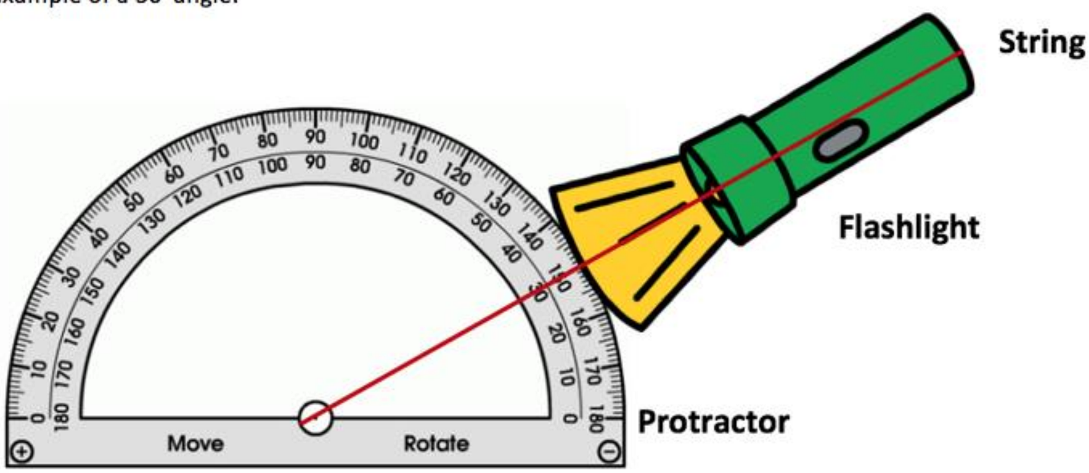
E) Rio De Janeiro, Brazil

Date	Latitude	Solar Declination	Solar Angle	Surface Area
March 21st				
June 21st				
September 21st				
December 21st				

Part III: Simulating Solar Angle

Before starting this phase of the lab, compare your solar angles with the group next to you to make sure your calculations are accurate. Once you have verified your solar angles continue.

On the paper provided for each city you will simulate the light intensity for each of the days of the year using the protractor and flashlight provided. Place the center of your protractor on the dot that indicates the city. Using the string, place the flashlight at the appropriate solar angle for each day that you calculated it for. Make sure the string lines up with the center of the flashlight and the correct angle. See picture below for an example of a 30°angle.

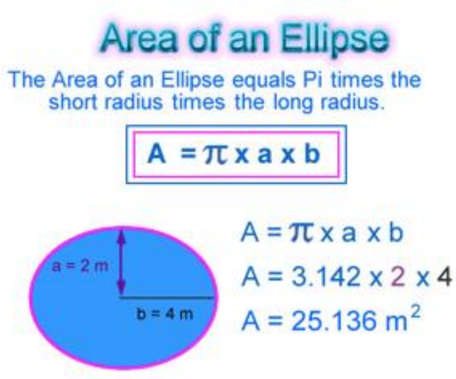


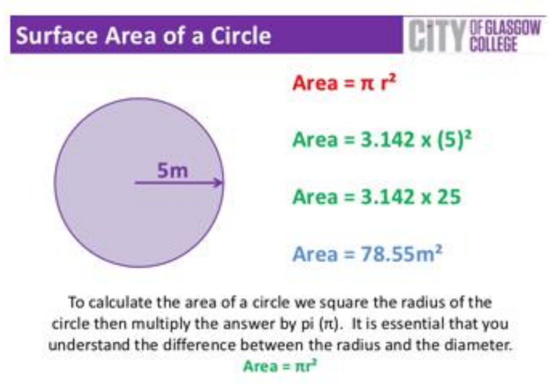
Once you have the light cast for a solar angle, trace the light projected on the paper with the colored pencils/markers that you have. Designate one color for each day that you calculated the solar angle for. For example, if you trace the December 21st light with blue for Quito then all December 21st lights should be traced with blue.

For each city trace the light for the 4 days that you calculated the solar angle. We will analyze these in the next section of the lab.

Part IV: Analyzing the Intensity of Light

If you recall, light intensity can be calculated by dividing power by surface area. Using the the tracings that you made for each city we will be able to calculate surface area for each solar angle. Use the formulas below to calculate the surface area for each tracing. Enter the surface area in the data table from Part II.





Part V: Drawing Conclusions

1. What is the relationship between light intensity and surface area of light?
2. What solar angle results in the most intense light? ___________
3. Does each city experience the same intensity of light throughout the year? ___________
4. For each city, what day of the year do they receive the most intense light?
   a. Quito, Ecuador ___________________
   b. Miami, FL ___________________
   c. St. Paul, MN ___________________
   d. Barrow, AK ___________________
   e. Rio de Janeiro ___________________
5. How do these results compare to what you predicted in Part I?
6. What city do you think has the warmest temperatures **throughout** the year? Justify your response using evidence from this lab.
7. What city do you think as the coolest temperatures **throughout** the year? Justify your response using evidence from this lab.
8. What do you think is the causes for <u>different places</u> on Earth receiving different intensities of light on the <u>same</u> <u>day</u>?
9. What do you think is the cause for the <u>same place</u> on Earth receive different intensities of light <u>throughout the year</u>?
10. Pick any place/city in the world that you would like to visit someday (must be outside of Minnesota).
    Predict the following: Location: ___________________
    a. Hottest day _____________ b. Coldest day _____________
    Using the computer, identify if your predictions were right or wrong. Explain why you think your were right or wrong. Think logically!

Table of the Declination of the Sun
Mean Value for the Four Years of a Leap-Year Cycle
Positive sign (+) Sun north of Celestial Equator; negative sign (-) Sun south of Celestial Equator.

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	-23°04'	-17°20'	-7°49'	+4°18'	+14°54'	+21°58'	+23°09'	+18°10'	+8°30'	-2°57'	-14°14'	-21°43'
2	-22°59'	-17°03'	-7°26'	+4°42'	+15°12'	+22°06'	+23°05'	+17°55'	+8°09'	-3°20'	-14°34'	-21°52'
3	-22°54'	-16°46'	-7°03'	+5°05'	+15°30'	+22°14'	+23°01'	+17°40'	+7°47'	-3°44'	-14°53'	-22°01'
4	-22°48'	-16°28'	-6°40'	+5°28'	+15°47'	+22°22'	+22°56'	+17°24'	+7°25'	-4°07'	-15°11'	-22°10'
5	-22°42'	-16°10'	-6°17'	+5°51'	+16°05'	+22°29'	+22°51'	+17°08'	+7°03'	-4°30'	-15°30'	-22°18'
6	-22°36'	-15°52'	-5°54'	+6°13'	+16°22'	+22°35'	+22°45'	+16°52'	+6°40'	-4°53'	-15°48'	-22°25'
7	-22°28'	-15°34'	-5°30'	+6°36'	+16°39'	+22°42'	+22°39'	+16°36'	+6°18'	-5°16'	-16°06'	-22°32'
8	-22°21'	-15°15'	-5°07'	+6°59'	+16°55'	+22°47'	+22°33'	+16°19'	+5°56'	-5°39'	-16°24'	-22°39'
9	-22°13'	-14°56'	-4°44'	+7°21'	+17°12'	+22°53'	+22°26'	+16°02'	+5°33'	-6°02'	-16°41'	-22°46'
10	-22°05'	-14°37'	-4°20'	+7°43'	+17°27'	+22°58'	+22°19'	+15°45'	+5°10'	-6°25'	-16°58'	-22°52'
Day	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
11	-21°56'	-14°18'	-3°57'	+8°07'	+17°43'	+23°02'	+22°11'	+15°27'	+4°48'	-6°48'	-17°15'	-22°57'
12	-21°47'	-13°58'	-3°33'	+8°28'	+17°59'	+23°07'	+22°04'	+15°10'	+4°25'	-7°10'	-17°32'	-23°02'
13	-21°37'	-13°38'	-3°10'	+8°50'	+18°14'	+23°11'	+21°55'	+14°52'	+4°02'	-7°32'	-17°48'	-23°07'
14	-21°27'	-13°18'	-2°46'	+9°11'	+18°29'	+23°14'	+21°46'	+14°33'	+3°39'	-7°55'	-18°04'	-23°11'
15	-21°16'	-12°58'	-2°22'	+9°33'	+18°43'	+23°17'	+21°37'	+14°15'	+3°16'	-8°18'	-18°20'	-23°14'
16	-21°06'	-12°37'	-1°59'	+9°54'	+18°58'	+23°20'	+21°28'	+13°56'	+2°53'	-8°40'	-18°35'	-23°17'
17	-20°54'	-12°16'	-1°35'	+10°16'	+19°11'	+23°22'	+21°18'	+13°37'	+2°30'	-9°02'	-18°50'	-23°20'
18	-20°42'	-11°55'	-1°11'	+10°37'	+19°25'	+23°24'	+21°08'	+13°18'	+2°06'	-9°24'	-19°05'	-23°22'
19	-20°30'	-11°34'	-0°48'	+10°58'	+19°38'	+23°25'	+20°58'	+12°59'	+1°43'	-9°45'	-19°19'	-23°24'
20	-20°18'	-11°13'	-0°24'	+11°19'	+19°51'	**+23°26'**	+20°47'	+12°39'	+1°20'	-10°07'	-19°33'	-23°25'
Day	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
21	-20°05'	-10°52'	**0°00'**	+11°39'	+20°04'	**+23°26'**	+20°36'	+12°19'	+0°57'	-10°29'	-19°47'	**-23°26'**
22	-19°52'	-10°30'	+0°24'	+12°00'	+20°16'	**+23°26'**	+20°24'	+11°59'	+0°33'	-10°50'	-20°00'	**-23°26'**
23	-19°38'	-10°08'	+0°47'	+12°20'	+20°28'	**+23°26'**	+20°12'	+11°39'	**+0°10'**	-11°12'	-20°13'	**-23°26'**
24	-19°24'	-9°46'	+1°11'	+12°40'	+20°39'	+23°25'	+20°00'	+11°19'	-0°14'	-11°33'	-20°26'	**-23°26'**
25	-19°10'	-9°24'	+1°35'	+13°00'	+20°50'	+23°24'	+19°47'	+10°58'	-0°37'	-11°54'	-20°38'	-23°25'
26	-18°55'	-9°02'	+1°58'	+13°19'	+21°01'	+23°23'	+19°34'	+10°38'	-1°00'	-12°14'	-20°50'	-23°23'
27	-18°40'	-8°39'	+2°22'	+13°38'	+21°12'	+23°21'	+19°21'	+10°17'	-1°24'	-12°35'	-21°01'	-23°21'
28	-18°25'	-8°17'	+2°45'	+13°58'	+21°22'	+23°19'	+19°08'	+9°56'	-1°47'	-12°55'	-21°12'	-23°19'
29	-18°09'	-8°03'	+3°09'	+14°16'	+21°31'	+23°16'	+18°54'	+9°35'	-2°10'	-13°15'	-21°23'	-23°16'
30	-17°53'		+3°32'	+14°35'	+21°41'	+23°13'	+18°40'	+9°13'	-2°34'	-13°35'	-21°33'	-23°12'
31	-17°37'		+3°55'		+21°50'		+18°25'	+8°52'		-13°55'		-23°08'

APPENDIX B

IRB EXEMPTION

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4706
cherylj@montana.edu

MEMORANDUM

TO: Samantha Berg and Eric Brunsell
FROM: Mark Quinn Mark Quinn CJ
DATE: December 7, 2016
SUBJECT: "*Incorporating Active Learning Strategies Focused on Contextual Data Analysis to Improve Student Engagement, Data Literacy, and Conceptual Understanding in Middle School*" [SB120716-EX]

The above research, described in your submission of December 7, 2016, 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, (i) if wholesome foods without additives are consumed, or (ii) 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 C

STUDENT ENGAGEMENT SURVEY

Earth Science Student Engagement Survey

Participation is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at any time and it will not affect your grade.

Read each statement below. In the boxes to the right of the question place one check mark in the box that corresponds with how much you agree with the statement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. In the last two weeks I have tried my hardest to complete all homework.					
2. In the last two weeks I have participated in class daily in some way, shape or form.					
3. In the last two weeks I have been able to focus in class.					
4. In the last two weeks I have felt actively involved in class.					
5. In the last two weeks I have collaborated (worked with) my peers to accomplish something in class.					
6. In the last two weeks information has been presented in multiple ways (verbally, visually, physically).					
7. In the last two weeks I have received feedback in class that helps my learning.					
8. In the last two weeks I have applied what we are learning in class to a realistic scenario.					
9. In the last two weeks I have enjoyed/been interested in the way we learned.					
10. In the last two weeks I feel like I have understood the material we covered in class.					

APPENDIX D

FOCUS GROUP QUESTIONS

Focus Group Questions

Participation is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at any time and it will not affect your grade.

Each student from the group must respond to the question provided, but students may respond in any order and at whatever length they wish.

1. How do you feel class is going academically? Am I teaching in ways that help you learn? Do you like the way that we have been learning?

2. Are you able to keep up with the pacing of the class? Is the pacing too slow or fast? Do you feel like your questions get answered?

3. How confident are you in what we are learning? Do you feel challenged? Can you connect what we are learning with the real world?

4. Overall, how do you feel about your data interpretation skills? Do you feel confident interpreting graphs and data tables? Do you feel confident creating graphs and data tables?

5. Do you feel like class is a place where you can safely and comfortably learn? Are social interactions positive within the classroom? Do you feel like like a valued member of the classroom (by your teacher or your peers)?

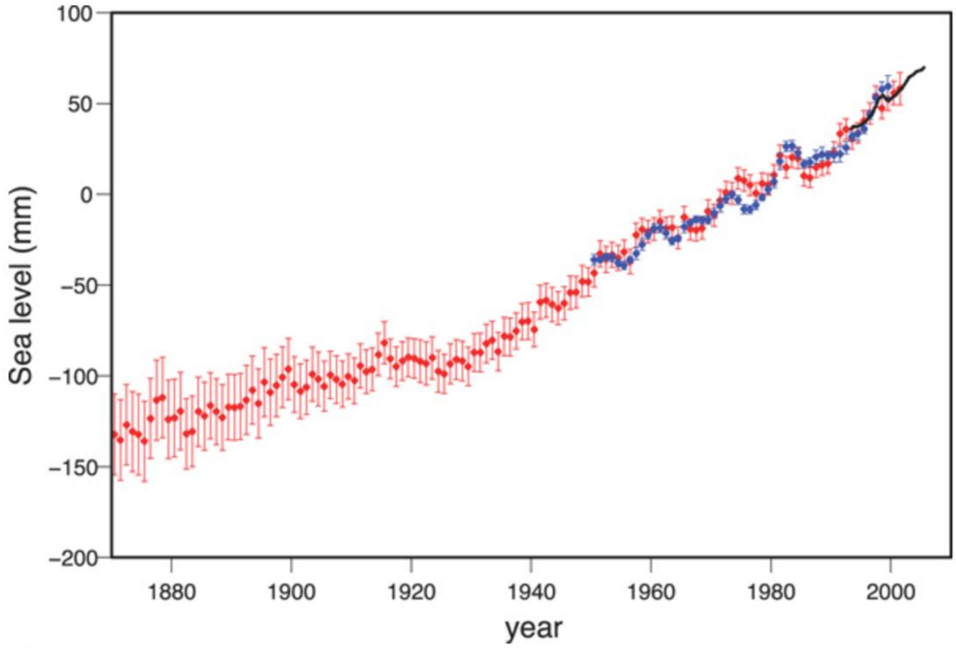
6. Do you feel like you are actively engaged in class most days? What does your ideal classroom look like?

APPENDIX E

DATA LITERACY PRE/POST TEST

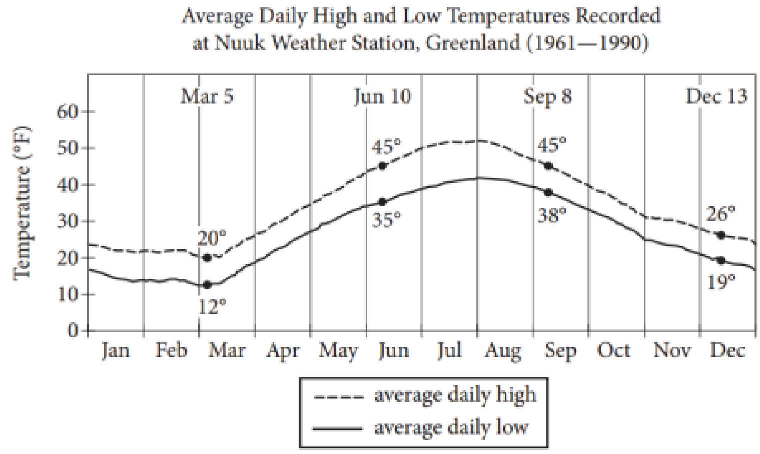
Data Analysis Pre-Test

Use the following graph to answer questions 1-5.



1. What information is shown on the x-axis of the graph?
    a. Time
    b. Sea level
    c. Temperature
    d. Error
2. Which of the following statements best describes the trends of sea level as shown in the graph?
    a. Sea level jumps around a lot over time
    b. Sea level decreases steadily through time
    c. Sea level increases steadily through time
    d. Sea level increases, but not steadily
3. Approximately how much did the sea level changed between 1950 and 2000?
    a. Sea level increased 50 mm
    b. Sea level decreased 50 mm
    c. Sea level increased 100 mm
    d. Sea level increased 150 mm
4. Which statement best describes the error associated with the measurements displayed in this graph?
    a. The error increases with time
    b. The error decreases with time
    c. The error stays the same over time
    d. There is no error with these measurements
5. **<u>Explain</u>** what would cause your answer for question 4.

Use the following graph to answer question 6-7
The size of the ice sheet fluctuates seasonally: in summer, average daily high temperatures in Greenland can rise to slightly above 50 degrees Fahrenheit, partially melting the ice; in the winter, the sheet thickens as additional snow falls and average daily temperatures drop.



Adapted from WMO. ©2014 by World Meteorological Organization.

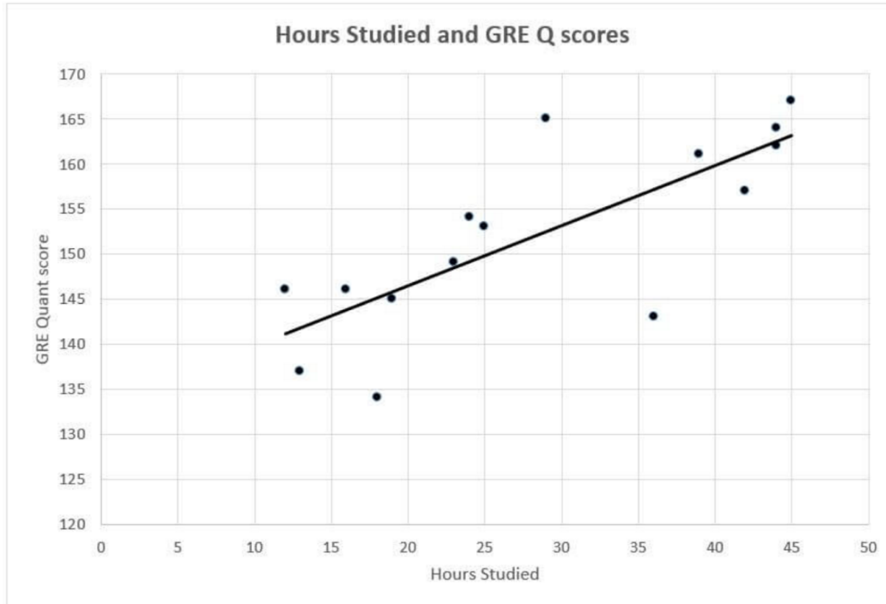
6. Based on the graph above, the average daily low temperatures can drop…
   a. There no change in temperature
   b. to 12 degrees Fahrenheit
   c. to their lowest point on December 13th
   d. to 10 degrees Fahrenheit and stay there for months

7. Based on the graph above, the difference between average daily high and average daily low…
   a. Stays the same throughout the year
   b. Is largest in the winter
   c. Is largest in the summer
   d. Is largest in the spring

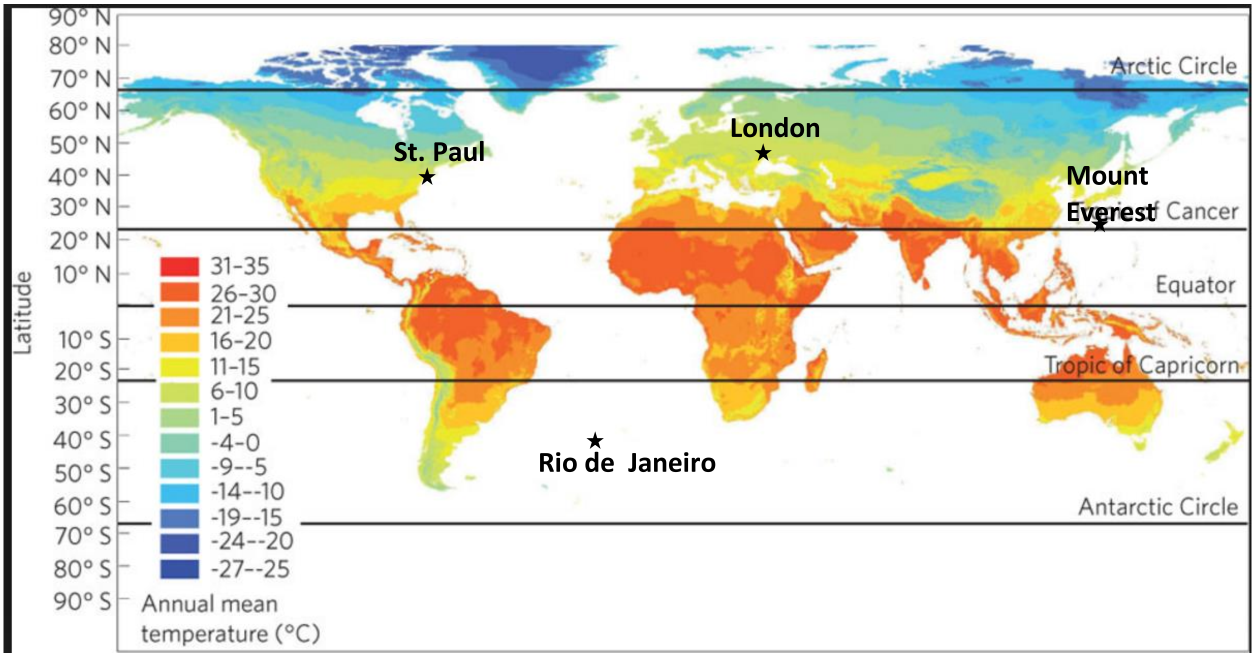
Use the following information and graph for questions 8-9.
Fifteen college seniors, none of whom took any math classes in college, were selected for a clinical trial. An online GRE Math Course was made available to them, and these students were allowed to study for however many hours they wanted. Then, each took the GRE for their first time. The graph below records how many hours each student studied, using the online material, and that student's GRE Quant score (final score). The best-fit line model shows the best prediction, given such a student's hours of study, of what her GRE Q score might be.

8. Among the students in this trial who studied less than 25 hours, what is the highest Quant score achieved?
   a. 146
   b. 149
   c. 154
   d. 157

9. For the students in this trial with the three highest scores, approximately what is the average number of hours they spend studying?
   a. 29
   b. 32
   c. 39
   d. 43



Use the following map for questions 10-14



10. According to the map, the hottest annual mean temperatures occur where?
    a. Right on the equator
    b. In between the Tropic of Cancer and Tropic of Capricorn
    c. Above the Tropic of Cancer and Tropic of Capricorn
    d. In the higher latitudes

11. Which hemisphere has a lower annual mean temperature on average?
    a. Northern
    b. Southern
    c. They are the same

12. Which city is at the highest latitude?
    a. Rio de Janeiro
    b. St. Paul
    c. London
    d. Mount Everest

13. Which city has the lowest annual temperature?
    a. Rio de Janeiro
    b. St. Paul
    c. London
    d. Mount Everest

14. Explain what would cause your answer for number 13.

Use the data table to the right to answer questions 15-16.

15. If a hurricane has winds of 240km/h and a pressure of 930 mb, what category is that hurricane?
    a. 2
    b. 5
    c. 3
    d. 4

16. What is the relationship between hurricanes and barometric pressure?
    a. The higher the wind speed, the higher the pressure
    b. The higher the wind speed, the lower the pressure
    c. The lower the wind speed, the lower the pressure
    d. There is no relationship between wind speed and barometric pressure

Hurricane Rating Scale

Category	Wind Speed (km/h)	Barometric Pressure (millibars)
1	119–154	>980
2	155–178	965–980
3	179–210	945–964
4	211–250	920–944
5	>250	<920

Use the data table below to answer questions 17.

Trial	Time (seconds)		
	Mouse 1	Mouse 2	Mouse 3
1	58	52	67
2	54	50	65
3	53	49	61
4	47	48	57
5	42	46	55

17. . A researcher placed three mice in a maze and recorded the time it took each mouse to complete the maze. Which relationship is best supported by the data collected by the researcher?

a. More practice reduced each mouse's maze completion time by more than 10 seconds

b. More practice resulted in faster maze completion times for each mouse.

c. More practice has no effect on maze completion times for each mouse

d. More practice had the greatest effect on Mouse 3's final completion time.