

THE EFFECTS OF SCIENTIFIC ARGUMENTATION ON STUDENT ATTITUDES  
AND EVIDENCE BASED REASONING SKILLS

by

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DEDICATION

This paper is dedicated to my dad, Kent Goodpaster, who taught me to value quality over quantity and that details of the simplest things are the most valuable of all.

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## ABSTRACT

For a scientifically literate society, there must be trust in the scientific community. This is only possible with an appreciation for the value of consensus, and the rigors that scientific consensus inherently requires. Students need more practice with construction and identification of valid explanations, in addition to more experience comparing and communicating multiple claims for the same question. Argumentation by evidence provides these opportunities and is the seventh practice of the Next Generation of Science Standards. This action research based project measured the effect student participation in a treatment consisting of five scientific argumentation activities on students' evidence-based reasoning skills, comfort levels and general attitudes towards science. Results showed slight improvement of evidence-based reasoning skills, a more complete understanding of scientific argumentation as a practice, and higher confidence and comfort levels when doing science. Results also indicated a slight improvement in students' abilities to identify valid evidence and reliable sources of information. This study also measured the types of evidence and quality of claims and justification provided by students during the treatment activities. Patterns seen in these measurements included common use of definitions as claims, inability to construct a concise yet sufficient claim, difficulty distinguishing claims from evidence, and a prevalent student viewpoint that providing justification for evidence is of less importance than providing evidence for claims.

## INTRODUCTION AND BACKGROUND

My prior teaching experience includes five years of sophomore biology and one year of AP biology for juniors and seniors at a small rural school in Checotah, Oklahoma. I currently work as a certified substitute for Springdale Public Schools in Springdale, a mid-sized city of approximately 73,000 in the northwest corner of Arkansas (Rollins, 2013). However, for this study I collaborated with Dr. John Graves' secondary science homeschool group of nine students from the Gallatin Christian Homeschool Cooperative in Bozeman, Montana.

Both my previous and current teaching experiences have led me to reflect on some student issues, both social and academic, that I have witnessed frequently in both school settings. Some observed issues of concern to me are the following:

- Students are extremely social amongst themselves, but hesitate to join academic conversations that involve sharing ideas and opinions about scientific topics. They are even more reluctant to be involved with classroom activities that involve commenting on other students' ideas or work.
- In general, students have a difficult time identifying valid, relevant, and reliable sources of information to use as evidence for supporting their own claims as well as identifying strengths and weaknesses of evidence used in claims by others.
- I over hear much banter in the students' daily conversations but rarely do I hear students use rational explanations to support their viewpoints; rather their arguments are usually settled with, "because that's how I feel."

As an attempt to gain insight and perhaps deeper understanding of these social and academic issues, I developed two goals for this action research based project. The first goal was to measure the effectiveness of using scientific argumentation activities to improve students' evidence-based reasoning skills. The second goal was to measure students' comfort levels and attitudes towards science before and after participation in these activities.

### CONCEPTUAL FRAMEWORK

Science education reform is a reality of today. Both the Common Core State Standards (CCSS) and the Next Generation of Science Standards (NGSS) are daily topics of conversations across the nation. However, it is not just talk. The CCSS are already in advance phases of implementation in many of the 45 states that have formally adopted them (Common Core State Standards Initiative, 2012). A bit behind the CCSS are the NGSS. As of June 11, 2015, fourteen states, including the District of Columbia, have formally adopted the NGSS. However, 26 states actively participated in the development of the standards. The NGSS are standards designed for today's students and tomorrow's workforce and are both rich in content and practice. They are arranged in a coherent manner across disciplines and grades K-12 to provide all students an internationally benchmarked science education (NGSS Lead States, 2013).

The Common Core standards were not specifically designed for the content of science education; however, they do lay a solid foundation for building strong literacy skills needed for use in scientific practices such as argument by evidence. For example, CCSS 6.1 writing standard requires students to write arguments to support claims with

clear reasons and relevant evidence. This emphasis on the use of argument in student thinking and writing is derived from the idea students build critical thinking skills when they practice identifying and citing relevant evidence to support their claims. Students also improve their critical thinking skills when they compare two or more texts or viewpoints (Common Core State Standards Initiative, 2012).

The argumentation skills proposed by CCSS are enhanced by the eight science and engineering practices of The Framework for K-12 Science education (National Research Council, 2012). This framework was the guiding force behind the development of NGSS. Practice number seven of the framework requires students to engage in argument from evidence. This practice allows students to distinguish between utilization of argumentation in science practices versus engineering practices. As defined by the National Research Council (NRC), science practices use reasoning and argument for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. In engineering practices, reasoning and argument are essential for finding the best possible solution to a problem. Regardless of whether a scientist or engineer uses the practice, both must collaborate with peers throughout the process in an attempt to reach consensus on the best solution to the question or problem at hand (NRC, 2012).

Students encounter many challenges when they are asked to create an evidence-based argument in science. One of the greatest challenges students have with scientific argumentation is acknowledging the difference between data and evidence (Sampson, 2013). Additionally, students lack the ability to transform data into evidence. This leads

to a misuse of data due to incorrect data analysis or other misinterpretations. Another difficult aspect to argumentation by evidence observed is the process of justifying evidence. Sampson claims most students do not understand the value of making their assumptions explicit to others, or they fail to discuss the theory, law or concept that guided their analysis and interpretation of the data they collected.

Other challenges for students when practicing argumentation by evidence include evaluating the conclusions of others in the science classroom (NRC, 2012). Sampson (2013) explains that many students, for cultural or other reasons, consider it disrespectful to question the ideas of their classmates, or they are inhibited by existing relationships with their peers. Other students see little value when discussing the merits of an idea, preferring to wait for the teacher or friends to reveal the right answer. When students do engage in argumentation with their classmates, they often do not argue from evidence but use personal attacks, an appeal to authority figures, or personal experiences or beliefs to support or challenge an idea. Most students, then, need more opportunities to learn how to participate in argumentation consistent with the norms and values of the scientific community.

Students need more opportunities to analyze and reflect on the thinking processes and analyze viewpoints of other students. This must take place in a safe environment of respect, a place that nurtures a diversity of ideas and facilitates collaboration between classmates (Liftig, 2013). The term “argue” should be understood in the correct context. In a science classroom, an argument should model a process that might be used by the scientific community. This process of argumentation is different from conventional

arguments. Llewellyn (2013) explains scientific argumentation as a higher-level, critical-thinking science skill, used to propose, support, critique, refine, justify, and defend one's position about a specific issue. The goal of a confrontational dispute is for one viewpoint to “win” over another's. Llewellyn clarifies scientific argumentation as different because as explanations are discussed, new ideas are generated, verified, communicated, debated, and modified in a way that is ultimately “win-win” because the goal in scientific arguments is to refine and build consensus for scientific ideas. This collaborative nature leads towards ever developing understanding of scientific phenomenon.

A simple search for any particular question online will likely give a long list of results, all similarly displayed as links that use approximately the same pixel space, but this is where the similarity ends. Each link leads to a different source of information, which may lie anywhere on the spectrum of reliability and validity. It is imperative students build the skill set needed to sort through a wide plethora of material that is freely available, 24 hours a day, from the internet and other information sources. Teachers can acknowledge this reality of abundant biased claims, bad science, and false evidence, and extrapolate learning opportunities for recognizing and identifying characteristics associated with valid and reliable evidence. Participation in scientific conversations and argumentation by evidence both require students to examine the strengths and weaknesses in associated claims and evidence. These types of activities should be commonplace in the classroom, regardless of grade level. Progression of accuracy in students' abilities for explaining and communicating science is a fundamental part of NGSS, and rightfully so. With the socio-scientific issues today, such as vaccinations,

climate change, and loss of biodiversity, the price is too high for societal decisions to be based on bad science, and time is too limited for delays in policy-making due to misrepresented uncertainties in evidence. Now more than ever, students need the ability and confidence to weigh evidence for themselves as scientifically literate citizens.

## METHODOLOGY

The treatment for this action research based project took 11 weeks, beginning in January and ending in April of 2015. The subjects of this study were a class of nine high school ecology students of the Gallatin Christian Homeschool Cooperative (GCHC), which meets once a week at the E-Free Church Building in Bozeman, Montana. GCHC is open to students aged 3 to 18 and many of the students have parents who volunteer their time to teach the various classes offered. The number of students fluctuates by semester, with approximately 60 students enrolled during the spring of 2015 (personal communication, J. Graves, April 1, 2015). 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 A).

The subjects in this study included five females and three males enrolled in a 13-week high school level ecology class instructed by Dr. John Graves. This GCHC class met together once a week, but class resources also included podcasts and an informational class webpage that were updated on a weekly basis. I was able to interact with the students via webcasts and view the student treatment activities, both live and through video recordings. These interactions coupled with email submissions of student

work, allowed me to personally interview each student, effectively observe student presentations during treatment and collect sufficient data for my project.

It is of importance to note the students were actively participating in an ecological investigation before and during the treatment phase of this project. The investigation required students to create his or her own biome jar that served as a model of a self-sustaining ecosystem. The students kept their biome jars at home and were required to make routine observations and measurements, which they logged in their science notebooks and shared with other classmates to create a class data set (Appendix B).

To achieve my two goals for this project, I developed three research questions. The first question was, *What is the students' skill level for evidence-based reasoning*. The second question was, *How comfortable are the students, based on self-assessment, in their ability to participate in oral and written assignments that require evidence based reasoning*. The third question was, *What are the students' attitudes towards science during problem solving using scientific argumentation*.

To help answer my research questions, I designed a course of treatment that consisted of five main activities. These treatment activities included oral presentations and written argumentation assignments, both of which required students to provide justification for any evidence they used to support a claim to an essential question. The questions used in these activities aligned with ecological concepts relevant to weekly lesson plans. Collectively, the treatment activities were on a continuum in relation to the amount of specific instruction given to the students, with the first activities having less explicit directions than those towards the end of the treatment phase.

The first treatment activity, Presentation 1, began with a request during the weekly podcast video for students to bring in a short presentation of observations they had made of their biome jars. Along with the minimal instructions, the students had flexibility in what type of format to use for their presentation. The video also included a brief statement that compared the assignment to the way in which scientists actually work; they come up with a question or questions, go out and gather information, and eventually share this information via their findings from the data. A recording was made of the student presentations during class and later posted as a link on the class website. After the presentations, introduction to the Oral Presentation Rubric outlined the specific components expected in future oral presentations (Appendix C). The students then self-assessed using the rubric while viewing their presentation using the class website link. The students submitted these self-assessed rubrics the next class period.

The second treatment activity, Presentation 2, occurred two weeks after Presentation 1. This second activity required students to answer one of three given questions or create their own question that was relevant to conditions they had observed within their biome jars (Appendix D). They were advised to use the Oral Presentation Rubric as a guideline when developing their presentation and emphasis was placed on including essential components of a scientific argumentation; question, claim, evidence, and justification of evidence. The student presentations, also video recorded, occurred the following class meeting.

The third treatment activity, Water Properties, required the students to first review components of a scientific argumentation by watching a podcast that highlighted the

differences between claims, evidence, and justification of evidence. Next, the students used their biome jars as reference and formulated an essential question related to water properties, a science concept recently discussed during class. Instructions for this activity then requested they use personal observations of their biome jars as evidence for their claim and justify their evidence using ecological concepts related to the properties of water. They submitted their responses using a Google document survey form (Appendix E). During this week, the students also completed a short google document survey that asked them to agree or disagree with the statement, *all evidence is data; but not all data is evidence*, and provide an explanation for their answer.

The fourth treatment activity, Plant Biomass, was a written argumentative essay modified from an activity found in *Scientific Argumentation in Biology* (Sampson & Schleigh, 2013). During this activity, the students chose one of three given explanations to the question, *where does most of the matter that makes up the stem and leaves of a plant come from* (Appendix F). They used the Written Argument Rubric as a guideline of what to include in their essay and were encouraged to use internet resources as needed (Appendix G). Similar to the rubric used for the oral presentations, the Written Argument Rubric's objectives explicitly stated for students to include evidence supporting their claim and justification of their evidence. They were also encouraged to utilize observations of their biome jars as potential supporting evidence.

A two-part argumentation activity served as the fifth activity and concluded the treatment phase. This activity, simply named the Final Project, required students to choose between three ecologically based issues and develop both an argumentative essay,

as well as a related oral presentation to share on the final day of class (Appendix H).

They used the Oral Presentation Rubric and the Written Argument Rubric to guide their assignment and had one week to prepare both. A classroom recording was made of the presentation and they submitted their essays for grading at the end of class.

The data collection instruments used to measure the students' evidence-based reasoning skills were designed with parameters that focused on skills necessary for each of three components essential to the practice of scientific argumentation; *claims*, *evidence*, and *justification of evidence*. The specific skills measured for the claims component were the abilities to identify and produce a relevant and scientifically accurate explanation for a question. The skills measured for the evidence component were the abilities to identify and produce valid evidence relevant to a claim, the ability to differentiate the terms *data* and *evidence*, and the ability to apply personal observations and data collected from their biome jar investigation as appropriate sources of evidence. Lastly, the skills measured for the justification of evidence component included the ability to link the evidence to the claim by providing relevant and scientifically correct reasons why the provided evidence used to support the claim was appropriate and sufficient.

To collect data for measurement of these specific evidence-based reasoning skills, students first completed the Pre-Treatment Quiz that measured their ability to identify valid sources of evidence for various claims (Appendix I). Additionally, this instrument measured both how accurately students identified common fallacies and weaknesses in examples of scientific argumentation, as well as their ability to accurately identify

sources of information from a given list that were acceptable for use as evidence. The students took this quiz again towards the end of the treatment period in the form of the Post-Treatment Quiz (Appendix J). To analyze the data from the two quizzes, I calculated both the normalized gain for each student, as well as the class mean. Normalized gain measures the fraction gained of the total improvement possible. Low gains are normalized gain scores that fall below a 0.3, while high gains are scores above a 0.7.

The actual treatment activities also provided opportunities for measurement of evidence-based reasoning skills. During the treatment period, the Oral Presentation Rubric and the Written Argument Rubric outlined the objectives of each treatment activity, in which the students scored one point if they met the objective and zero if they did not. The sum of the points received reflected the final score. These scored rubrics provided a means to discover patterns indicative of strengths and weaknesses in specific skills essential to the practice of scientific argumentation. After the treatment period, data associated with patterns found in the scored rubrics was examined in more detail using the Scientific Explanation Rubric (SER) (Appendix K).

Measurements obtained using the SER were limited to the same outlined parameters as the other data collection instruments used to measure evidence-based reasoning skills, but focused on whether or not the three main components of a scientific explanation (claim, evidence, justification of evidence) were present in each submitted treatment activity, and if so, at what level of quality. The quality levels measured for the justification component included whether or not the justification was appropriately used

to link the evidence to the claim, and whether or not the justification was scientifically accurate.

The level of quality for the claims component was measured for relevancy, sufficiency, clarity, and conciseness. Claim conciseness was additionally measured by placing the claims considered to have excess information, which was any portion of their claim that was not necessary and essential, into one of two categories. The first category was claims with excess information that might have been more effectual if used as evidence, and the second category was assigned if the excess information might have been more effectual if used as justification.

The quality levels measured for the evidence component included whether or not it supported the claim, and what type of evidence it was. The types of evidence were represented by four categories, personal observations, textbook or online information, material provided or likely discussed during class, and personal opinion.

Collection of data used to measure conceptual understanding of the practice of scientific argumentation came from student responses to two open-ended questions, *what is evidence* and *what is scientific argumentation*, which were also part of the Reasoning Skills Quiz. Comparison of the students' responses from Pre-Treatment Reasoning Skills Quiz to the Post-Treatment Reasoning Skills Quiz provided measurements of growth in the students' understanding of scientific argumentation as a practice as well as a measurement of the students' ability to define the term evidence.

Student responses from the short Google survey that asked them to explain why they agreed or disagreed with the statement, *all evidence is data, but not all data is*

*evidence*, provided information used to measure the students' ability to differentiate the terms, *data* and *evidence*, and allowed for identification of any existing misconceptions about either term. Additional measurement of the students' ability to differentiate data from evidence and potential misconceptions of the two terms was possible using the students' justification of their responses to the question, *is there a difference between data and evidence*, asked during the Student Interview Questions (Appendix L).

To collect data on student attitudes, and help answer my two research questions, *How comfortable are the students, based on self-assessment, in their ability to participate in oral and written assignments that require evidence based reasoning* and, *What are the students' attitudes towards science during problem solving using scientific argumentation*, students completed the Pre-Treatment Student Survey (Appendix M). This survey was a modified and condensed version of a questionnaire titled, "The affective elements of science learning: a questionnaire to assess and improve student attitudes toward science," published in the NSTA monthly journal, *The Science Teacher* (2011). The original survey was designed to elicit responses from students that reflect their attitudes towards science, problem solving, and how comfortable they are when commenting on other student's work and presenting their ideas to others. A four point Likert scale served as the survey response options. In this scale, a 1 represented a student attitude of *Strongly Agree*, a 2 signified *Agree*, a 3 signified *Disagree*, and a 4 indicated *Strongly Disagree*. To analyze the data from the Pre-Treatment Survey, I averaged the responses of the whole group for each question. Repetition of this data collection process occurred after treatment with responses from the Post-Treatment Student Survey

(Appendix N). I was then able to identify positive or negative changes in these averages, reflected as a percent. Responses from the Student Interview Questions provided information for further analysis of student attitudes towards science and problem solving. In an effort to answer my focus questions using both quantitative and qualitative data and ensure use of multiple methods of data collection for each question investigated during this study, I constructed a framework for data collection represented by a Data Triangulation Matrix (Table 1).

Table 1  
*Data Triangulation Matrix*

Research Questions	Data Source 1	Data Source 2	Data Source 3
What is the students' skill level for evidence based reasoning?	Pre-Treatment Reasoning Skills Quiz	Post-Treatment Reasoning Skills Quiz	Treatment Activity Rubrics
How comfortable are the students, based on self-assessment, in their ability to participate in oral and written assignments that require evidence based reasoning?	Pre-Treatment Student Survey	Post-Treatment Student Survey	Student Interview Questions
What are the students' attitudes towards science during problem solving using scientific argumentation?	Pre-Treatment Student Survey	Post-Treatment Student Survey	Student Interview Questions

## DATA AND ANALYSIS

Results of the Pre-Treatment Reasoning Skills Quiz indicated that 67% of students correctly chose, *interview of an expert*, as being a valid source of information to use as evidence ( $N=9$ ). Post-Treatment Reasoning Skills Quiz responses to the same

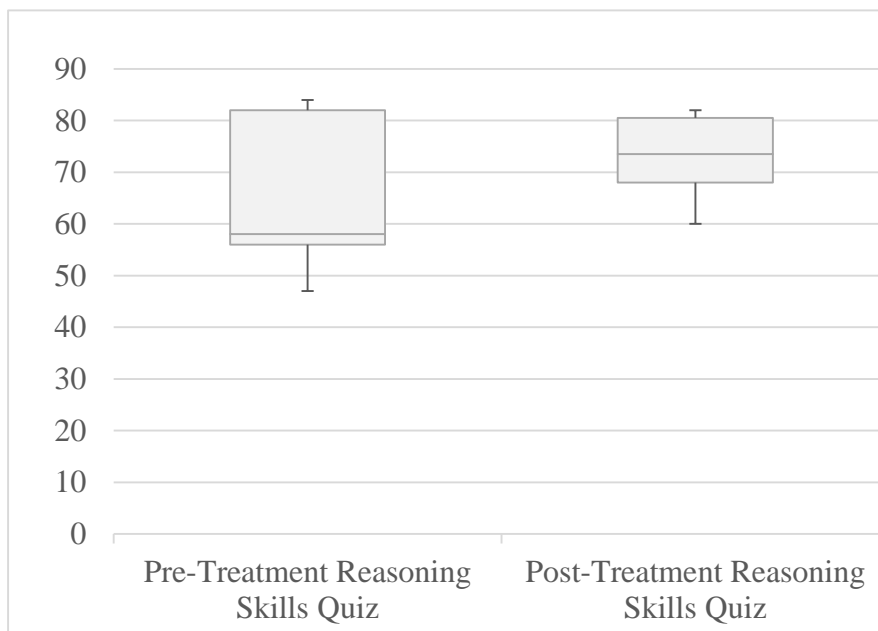
answer choice indicated that 100% of students considered interviewing experts as being a valid source of information for evidence (n=6).

A comparison of results from the Pre-Treatment Reasoning Skills Quiz and the Post-Treatment Reasoning Skills Quiz show the averaged normalized gain,  $g = .029$ , was very small, the mean score increased, but the maximum score remained nearly the same. The values for variance and significant difference showed the most change between the two quizzes, with decreased values for both (Table 2).

Table 2  
*Comparison of Assessed Values from the Pre-Treatment Reasoning Skills Quiz and Post-Treatment Reasoning Skills Quiz*

Student ID	Pre-Treatment Reasoning Skills Quiz	Post-Treatment Reasoning Skills Quiz	Normalized gain
1	47	60	.245
2	84	82	-.125
3	53	82	.617
4	84	71	-.812
5	76	76	0
6	56	67	.25
7	58	-	-
8	58	-	-
9	82	-	-
Normalized gain average			.029
			Change
Mean	66	73	7
Median	58	74	16
Mode	N/A	82	-
Min	47	60	13
Max	84	82	-2
Variance	196	63	-133
Significant difference	14	8	-6

Due to the wide range of individual normalized gains values along with decrease of -133 in the variance of the scores, I created a paired box and whisker plot for a more detailed comparison of the distribution ranges between the two quizzes. The Post-Treatment Reasoning Skills Quiz's interquartile range (IQR) was more evenly distributed and had a lower value of 20.5 compared to the Pre-Treatment Reasoning Skills Quiz, which had an IQR value of 35 (Figure 1).



*Figure 1.* Comparison of distribution range of scores from the Pre-Treatment Reasoning Skills Quiz ( $N=9$ ) and the Post-Treatment Reasoning Skills Quiz, ( $n=6$ ).

During the Student Interview Questions, 34% of the students said they had previous experience with classroom assignments that required supporting a claim with evidence, and 50% of the students were either unsure or claimed there was no difference between data and evidence ( $n=8$ ).

Since I had a small sample size in addition to not being able to calculate normalized gains for a third of my subjects, I invested more time towards measuring the

evidence-based reasoning skill levels evident in the students’ completed assignments from the five treatment activities. Results from the SER indicated that of the 40 treatment activities assessed, 7% contained no claim and 78% of the provided claims were relevant to the associated question. Relevancy aside, 60% of the provided claims included excess information. This excess information was closely divided between being better suited for use as evidence to support the claim or as justification of the evidence. Additionally, 20% of claims were indistinguishable from evidence and 15% of claims provided were not sufficient because they were definitions (Figure 2).

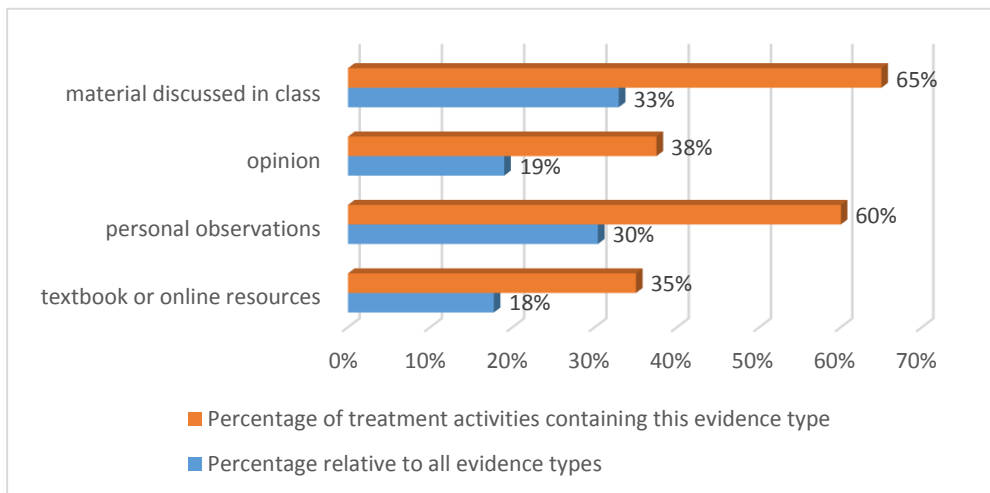
no claim provided 7%	no claim provided 7%	no claim provided 7%	no claim provided 7%
claim was not relevant to question 15%	definition used for the claim 15%	claim indistinguishable from evidence 20%	part or all of claim more effectual as evidence 27%
claim was relevant to question 78%	claim was too general or vague 25%	claim present, but not initially clear 20%	part of all of claim more effectual as justification 33%
	claim was sufficient 53%	claim clearly present 53%	no excess information in claim 33%
Claim Relevancy	Claim Sufficiency	Claim Presence	Claim Conciseness

Figure 2. Comparison of claim relevancy, sufficiency, clarity, and conciseness, from all 40 graded treatment activities.

From all 40 submitted treatment activities, I differentiated 79 individual pieces of evidence, which include the instances when evidence was not distinguishable from the claim, into one of four categories. The first category *material discussed in class* was assigned to evidence pieces that had similarities to current or previous classroom topics and assignments and fairly easy to recognize as paraphrased by the student. The second category *personal observations* consisted mostly of measurements and visual

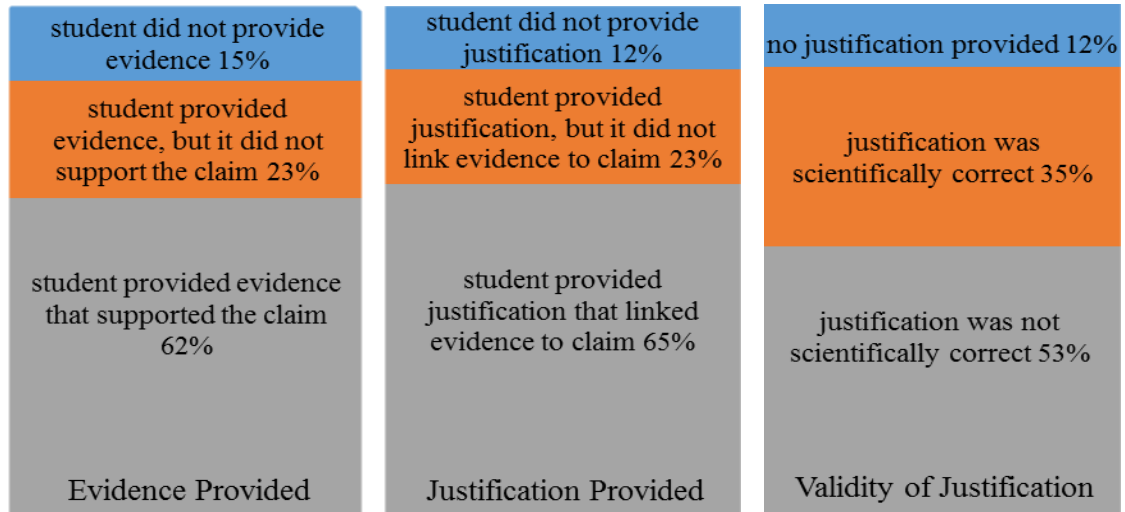
observations the students had made of their biome jar investigation. The third category *personal opinion* included anything not linked to personal observations and lacked scientific reasoning. The fourth category *textbook or online resources* was identifiable even though very few submitted assignments included cited references. Evidence pieces placed in this category had clear contrast between the writing style of the evidence piece and the student's style of writing throughout the rest of the assignment. Many of these were specific definitions written in a technical tone and less paraphrased than other evidence categories, making it more likely it was retrieved verbatim from an outside resource and not material covered in class.

The relative usage for each category of evidence was calculated from two perspectives, both proportionally equivalent and refer to all 79 pieces of evidence identified in the 40 submitted treatment activities. These two calculations provided the percentage of treatment activities that contained each category of evidence and relative usage of each category of evidence compared to the other three (Figure 3).



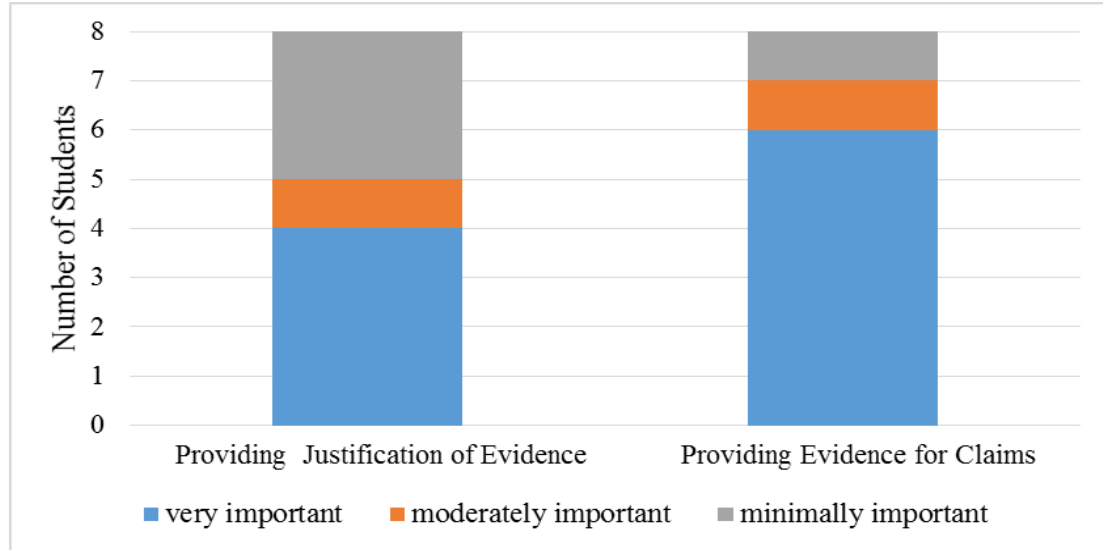
*Figure 3.* Percentage of treatment activities containing each evidence category and relative use for each evidence category.

Results from the SER also indicated that 62% of the treatment activities contained evidence that supported the claim, and 65% of the activities contained justification that linked the evidence to the claim. However, 53% of the justification provided was scientifically incorrect (Figure 4).



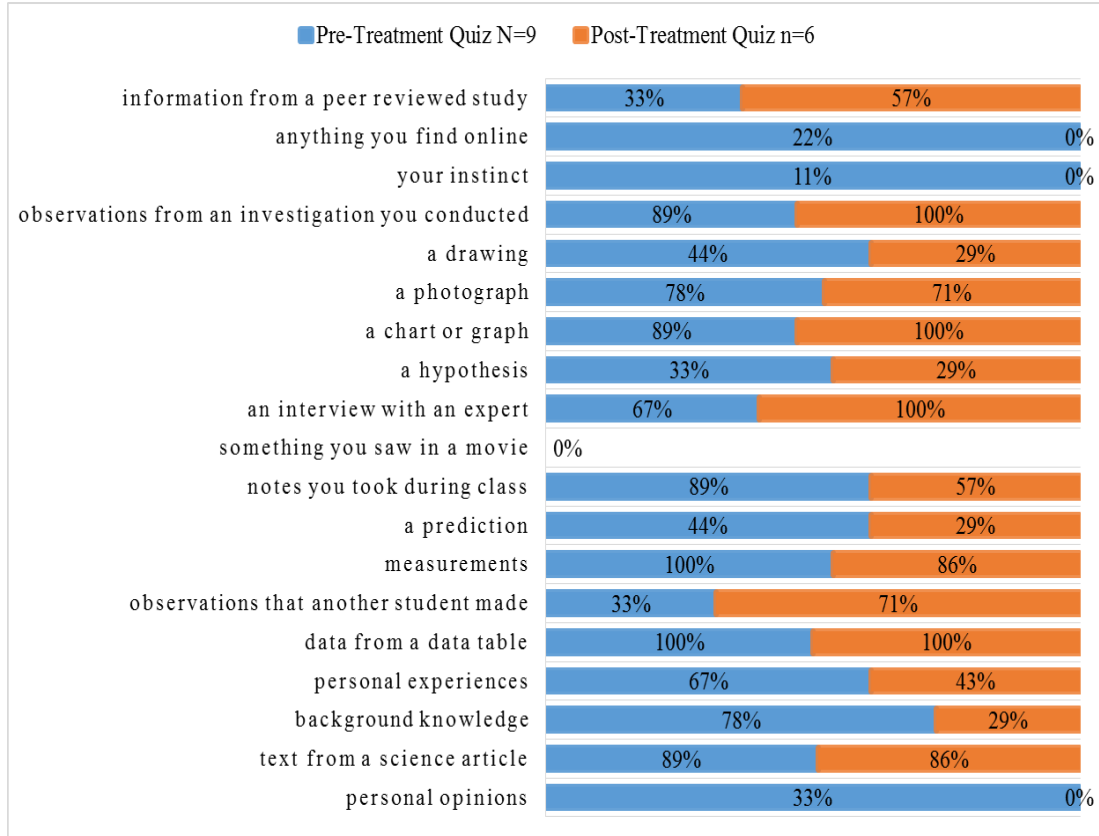
*Figure 4.* Relative levels of quality for evidence and justification of evidence provided in the students' treatment activity assignments.

Two Student Interview Questions, which provided students with a scale to rank importance, provided student feedback that indicated the students placed greater importance on providing evidence to support a claim than providing justification for any evidence used, and did not view evidence and justification as having equal importance (Figure 5).



*Figure 5.* Student feedback regarding importance placed on providing evidence for claims compared to the importance of providing justification for evidence, ( $n=8$ ).

Changes in the students' ability to recognize valid sources of information to use for evidence was possible by comparison of the Pre-Treatment Reasoning Skills Quiz to the Post-Treatment Reasoning Skills Quiz. Both versions of this quiz contained the same list of 19 information sources and instructed students to select only the ones they considered appropriate for use as evidence. For grading purposes, seven from the list were considered inappropriate sources for evidence. These seven information sources were *anything you find online, your instinct, a hypothesis, something you saw in a movie, a prediction, background knowledge, and personal opinions*. The remaining twelve on the list were graded as appropriate sources for evidence (Figure 6).



*Figure 6.* Comparison of Pre-Treatment Reasoning Skills Quiz and the Post-Treatment Reasoning Skills Quiz for information sources chosen as valid sources for use as evidence, by percent.

Alternately, the students' choices from the information source list allowed for calculation of change in the percent of incorrect answers chosen between the two quizzes, which seemed a more informative approach to gauge growth of students' conceptual understanding of valid evidence that occurred during treatment. To do this, I created two categories of incorrect answers. The first category compared the percentage of invalid information sources chosen (Figure 7). The second category compared the percentage of valid information sources not chosen (Figure 8).

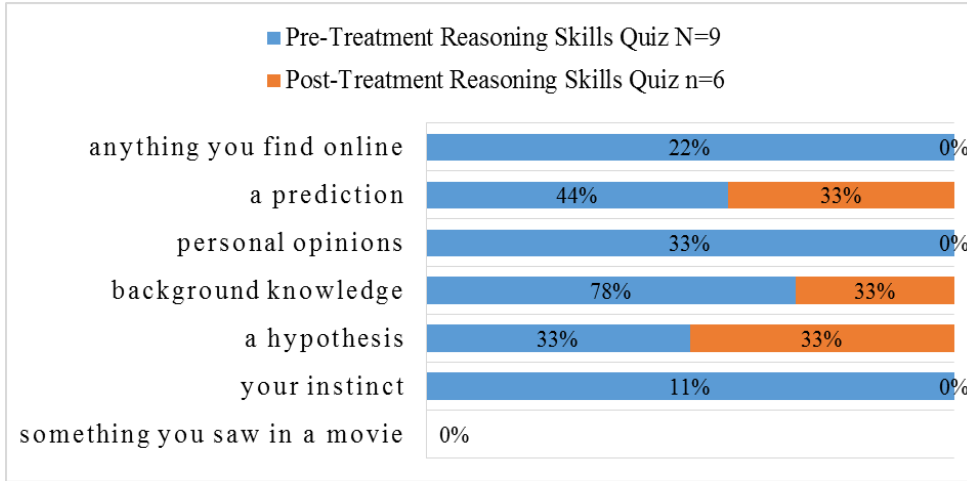


Figure 7. Comparison of incorrect answer responses by percentage for invalid information sources chosen in the Pre-Treatment Reasoning Skills Quiz and the Post-Treatment Reasoning Skills Quiz.

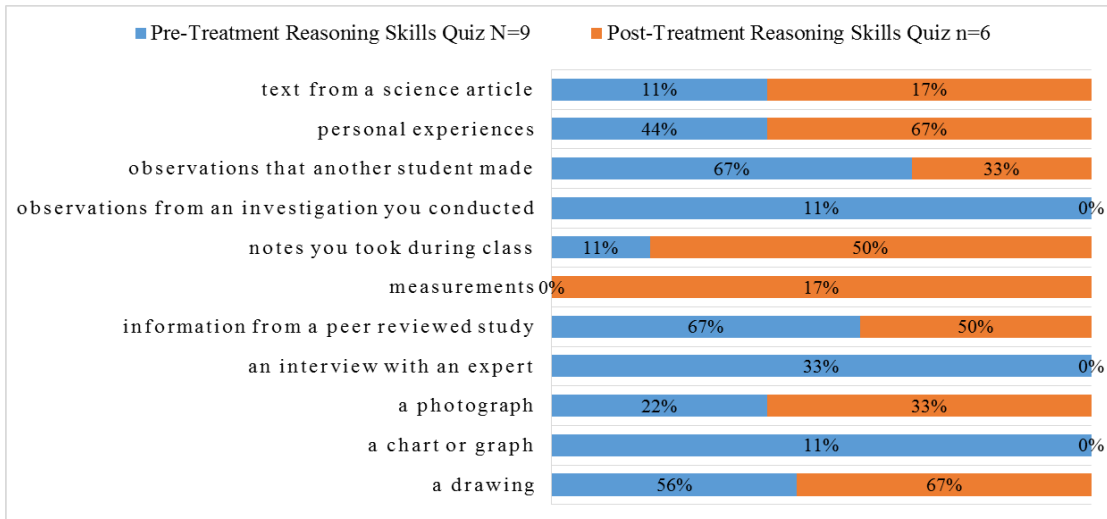


Figure 8. Comparison of incorrect answer responses by percentage for valid information sources not chosen in the Pre-Treatment Reasoning Skills Quiz and the Post-Treatment Reasoning Skills Quiz.

The information source list on both quizzes followed with an open-ended question, which asked the students to explain the rule they used when choosing sources of information appropriate for evidence. The majority of student responses on the Pre-Reasoning Skills Quiz included the word *proof* in their answer. Some examples of these

responses are, “It has to be proof from an observation I have made on a test I have conducted.” Another student said, “Being able to show proof of what you are explaining.” Another student response, “Has to be studied and concluded physical proof.” Other students’ explanations for the rule they used were so eccentric that I had a hard time categorizing it. A good representation of this type of response is, “It has to relate to the subject at hand, and it has to be fact. No - this skull is thought to be ten thousand years old. Therefore, the earth must be over ten thousand years old.” Another hard to categorize explanation was, “First of all pictures are least likely to lie. So that’s why I think pictures are wonderful evidence.”

Student explanations of their rule for determining valid evidence from the Post-Treatment Reasoning Skill Quiz showed less use of the word *proof* as a defining factor and many replaced it with descriptors such as *reliable*, *data*, and *credible*. Some examples of these student responses are, “For me to have marked something on the list it had to be something that would be credible and something that everyone would agree was evidence.” Another student wrote, “Data that has been collected concerning the subject.” Another example of a post-treatment explanation of the student’s rule for determining valid evidence sources was, “If it was something reliable.”

Responses from the Pre-Treatment Student Survey compared to the Post-Treatment Student Survey indicated slight changes in attitudes towards science in general. These responses were from the Likert items, which asked the student to respond with a *1* if they strongly agree, *2* if they agree, *3* if they disagree, and *4* if they strongly disagree. When comparing mean values between the two quizzes, the statement

indicating the most change was, *It is important to be able to create scientific explanations*, with a 21% change favoring more agreement on average. Another item that showed some of the greatest change was, *I understand the language of science*, with an 18% change favoring more agreement on average (Figure 9).

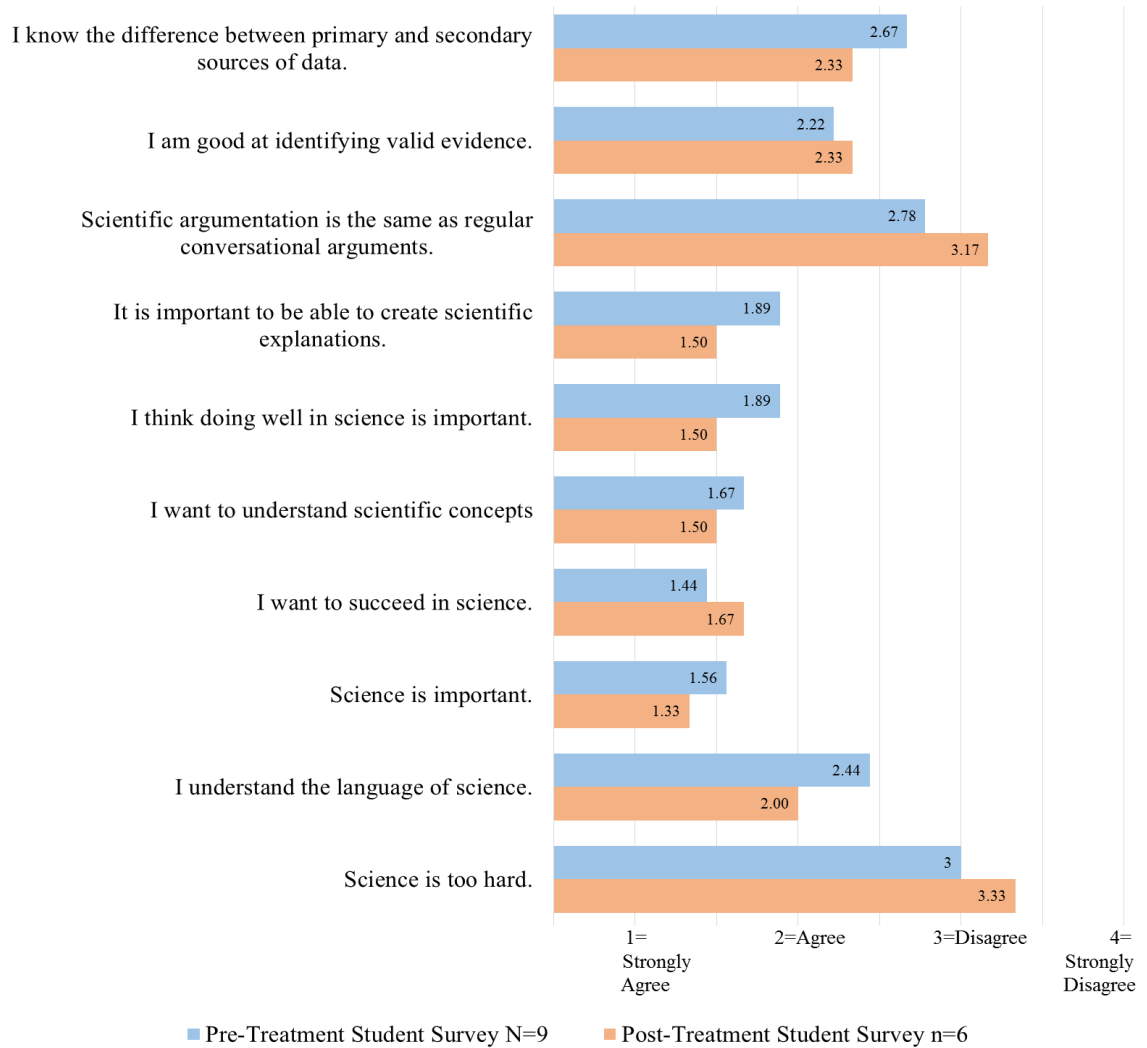


Figure 9. Comparison of averaged student responses on the Pre-Treatment Student Survey and Post-Treatment Student Survey for the Likert scale items relevant to student attitudes towards science.

The Likert items regarding student comfort and confidence levels when participating in evidence-based reasoning activities were compared in a second chart.

This separation allowed focus on my associated research question. The largest change seen within these items was from the statement, *I feel safe speaking my thoughts in science class*, with 28% change favoring more agreement on average (Figure 10).

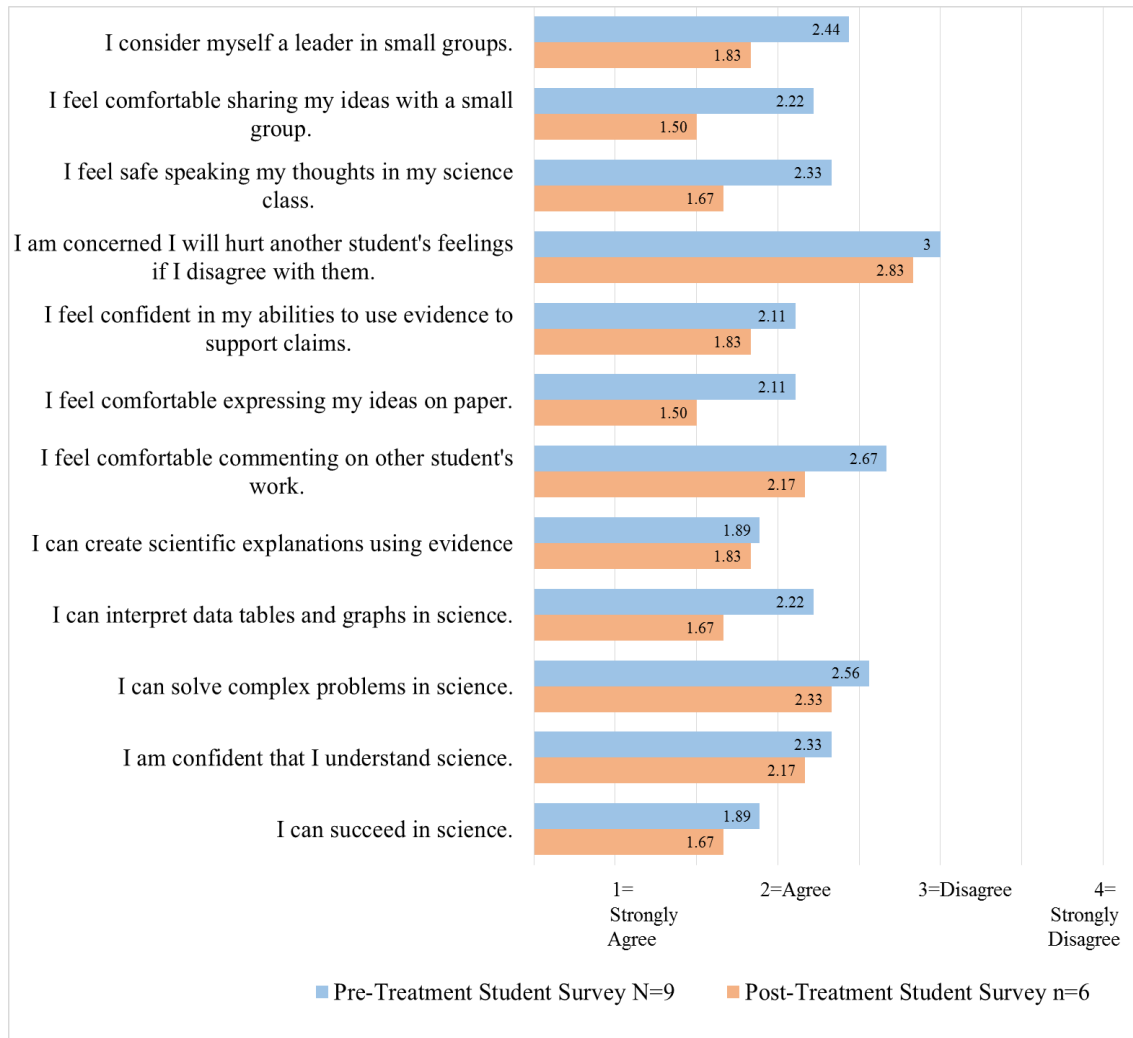


Figure 10. Comparison of averaged student responses on the Pre-Treatment Student Survey and Post-Treatment Student Survey for the Likert scale items relevant to student confidence and comfort levels.

The Student Interview Questions included two questions regarding their comfort levels during activities that require them to share ideas with the class as individuals or

require them to comment or review other classmates' work. Responses to both questions indicated the majority of students were comfortable or mostly comfortable when required to participate in such activities (Figure 11).

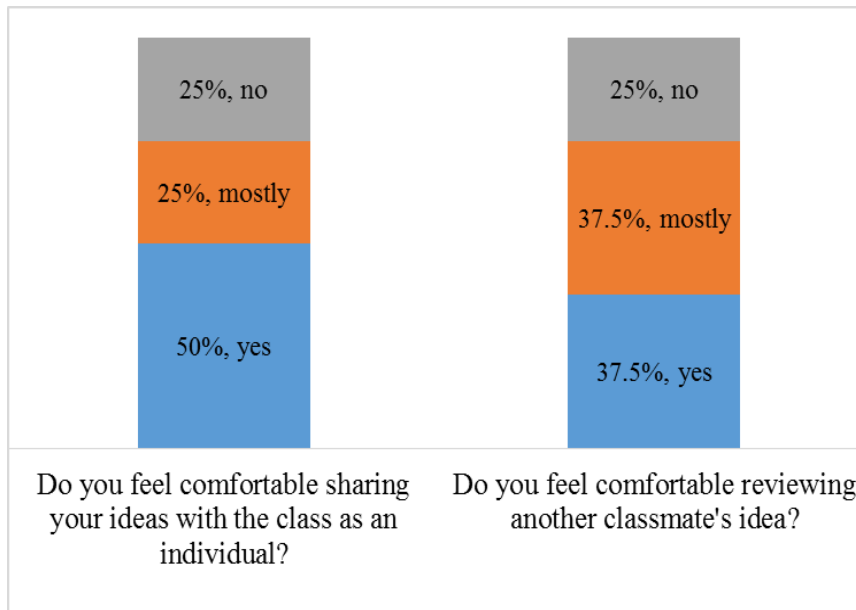


Figure 11. Student Interview Question responses by percent for two questions regarding comfort levels when sharing ideas or reviewing other classmates' ideas, (n=8).

Growth in students' conceptual understanding of scientific argumentation as a practice was evident from measurements obtained from two sources, the Student Interview Questions and the Pre and Post-Treatment Student Survey. Changes in responses from the open-ended survey question, *in your own words, define scientific argumentation*, indicated that the majority of students' definitions improved in quality. An example that indicated growth was a Pre-Treatment Student Survey response of, "the argument about things that God created." Compared with the same student's response on the Post-Treatment Student Survey of, "the discussion between different theories or concepts." These survey responses can also be compared with the Student Interview Question that asked, *what does scientific argumentation mean to you*. The Interview

Questions were asked approximately mid-way through the treatment activities. Another example of growth in student understanding of scientific argumentation as a practice came from one student's Pre-Treatment Student Survey response of, "an argument using scientific evidence from both sides." Compared with their Student Interview Question response of, "scientific argumentation means arguing from evidence using evidence, claims, justification to prove your claim, so you're arguing from science and your evidence."

### INTERPRETATION AND CONCLUSION

The first goal of my study was to measure the effectiveness of scientific argumentation activities on the students' evidence-based reasoning skills. While this goal specifically states argumentation activities, minimal emphasis placed on the rebuttal/defense component of scientific argumentation during the treatment activities makes it questionable if the treatment activities I used were truly *argumentation* activities. I resolve this by clarifying all activities required student argumentation by evidence, as all treatment activities required students to justify how the evidence they used supported their claim to the originating question. Additionally, high interdependence between the practices of constructing a scientific explanation and scientific argumentation, require students to have a solid understanding of the individual components of a scientific explanation before effective comparison between multiple explanations can occur. The second goal was to measure any changes in the students' comfort levels and general attitudes towards science after participation in these treatment activities. I think both goals could use more investigation as well as more participants,

but I believe I was successful in obtaining measurements that were appropriate sources of data for determining students' ability to produce a valid scientific explanation, as well as measure student attitudes towards science and comfort levels while participating in the treatment activities.

Due to such a small sample size, I am hesitant to say *how* effective the treatment activities were in building evidence-based reasoning skills, but I have no hesitancy claiming the treatment activities provided experiences that contributed to growth of the students' ability to identify and create a scientific explanation.

Results show that the students' skill levels for identifying valid sources of evidence improved, as well as their ability to articulate what valid evidence means. While confusion still existed towards the end regarding if there was a difference between data and evidence, the fact they were applying their personal observations of their biome jars as data for evidence to support claims confirms they were actively learning about the application aspect of data, which is fundamental for being able to differentiate data from evidence. These are not my personal students, but I think all are on the right track for being able to differentiate data from evidence because they now have the personal experience that not all measurements and observations they made were necessarily applicable to the claim, only the relevant data could be used as evidence. Furthermore, I believe the biome-jar investigation was an incredible method to introduce one way scientists actually work, by collaboration of their personal data. Support of this claim can be inferred from the increase in the percentage of students who correctly identified

*observations made by others* as a valid source information to use for evidence between the two quizzes.

A trend that I did not anticipate to see was such a small portion of the students' completed treatment activities that included sufficient claims that were both relevant to the question and yet concise in their structure. Granted, this would not have been as obvious nor relevant if I had not used rubrics that required verbatim specification of what I interpreted to be their claim, evidence, and justification within their writing or presentation. It was difficult to distinguish these components from each other, and often I saw how it would have been easier for the student to minimize their claim and realize part of the evidence or justification they need is already there. I believe this difficulty in assessment decreased both accuracy and validity of the skill levels measured in this study, as the student may have intended for something to be a component other than what it was graded as, whether claim, evidence, or justification.

As far as comfort and confidence when participating in the argumentation activities, both the responses to Student Interview Questions and changes reflected in the Likert items from the student surveys suggest that participation in the treatment activities positively influenced their attitudes towards science. Additionally their confidence in being able to do science, and comfort levels when required to express their ideas using evidence-based reasoning increased after participation in the treatment activities.

#### VALUE

This action research based project has provided multiple revelatory learning experiences that I did not consider during the initial design of my project, but indeed

became some of the most meaningful aspects. Some examples of these revelations, in no particular order, are the efficiency and effectiveness of collaborating online to generate and gather data that were valid representations of my subjects located 1,400 miles away. Second, the importance of conciseness when providing explanations, as the succinctness of claims directly relates to the strength and relevancy of supporting evidence. My third unexpected learning experience was the realization that the ubiquitous classroom assignment of having students provide definitions as answers when learning new terms and concepts is not only a time filler but also a time waster. As teachers, we are providing a disservice to students by allowing cut and paste answers to serve as quality learning experiences for understanding scientific explanations. Rather, the teaching and learning strategies for new terminology should be redirected towards providing opportunities for students to gain awareness that definitions have a function. The function of definitions, like concepts, theories, and laws, are to serve as essential resources that, when appropriate, are used to validate and link evidence to claims. Argumentation by evidence is a practice perfectly suited for this type of learning opportunity.

As a society, trust in scientific consensus should be the norm; unfortunately, today it is far from the norm. When students know that the scientific practice of argument by evidence is something within their ability to do, they have taken the first step towards appreciating what valid and reliable means, and move closer towards understanding the value of scientific consensus. This appreciation for the value of consensus is the fulcrum for development of trust in the scientific community. Until trust and understanding of the

scientific process becomes the norm, acceptance or rejection of ideas based on evidence will play a minimal role in societal decision-making.

The process of participating in an action research based project has increased my own confidence as a teacher with the realization that trying out a new approach to something is not such a risk. With experience designing methodology and learning to construct appropriate data collection instruments to obtain valid and accurate measurements, I know I can effectively test interesting new ideas with efficient use of time, therefore minimizing the risk that has hindered me from trying new teaching approaches in the past. Learning the process of action research has given me confidence in evaluating cause and effect. Change is inevitable, and with science education finally taking its turn at standardizing the scope and sequence of science content, and with NGSS encouraging new teaching strategies that involve crosscutting concepts and interdisciplinary learning, this confidence in determining if new practices and methods are effective could not have come at a better time.

Lastly, through the process of reflection required throughout my capstone experience, I now know that questions that result in answers that lead to more questions, is only an indication that perhaps a meaningful investigation has been initiated, and does not mean I have failed to answer the originating question. This perspective puts my mind at ease. The teacher never ceases to be a student during this cyclical journey of questioning and discovery.

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APPENDICES

APPENDIX A  
IRB VERIFICATION



**INSTITUTIONAL REVIEW BOARD**  
For the Protection of Human Subjects  
FWA 00000165

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Office of Human Subjects  
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FAX: 406-994-4103  
Email: cherylj@montana.edu

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**MEMORANDUM**

**TO:** Kelly Goodpaster and John Graves  
**FROM:** Mark Quinn, Chair *Mark Quinn CJ*  
**DATE:** December 5, 2014  
**RE:** "The Effects of Scientific Argumentation on Student Attitudes and Evidence Based Reasoning Skills"  
[KG120514-EX]

The above research, described in your submission of December 5, 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:

- (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.
- (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) (8) 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 B  
BIOME JAR INVESTIGATION

### BIOME JAR INVESTIGATION

Example of student data shared as a class set using google documents and a picture of the biome jar apparatus, which eventually included a fish in the water below and grass growing in the soil above



TEST	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9
GH	180	180	180	120	120	120		160	105
KH	120	120	120	180	180	190		113	135
PH	8	7	7.5	7	7.5	7		8.1	7.4
NO2			0	10	1	1.4		0.5	5
NO3	20	80	40	200	20	40		80	50
Grass height (CM)	23	23	28	23	21	5.08		14	12.7

APPENDIX C  
ORAL PRESENTATION RUBRIC

## ORAL RUBRIC

Aspect of the Argument	Point Value		Comments or Suggestion
	0	1	
<b>The Question</b>			
The question is sufficient			
<b>The Claim</b>			
The claim is sufficient			
The claim is accurate			
<b>The Evidence</b>			
Includes data			
Includes an analysis of the data			
Includes an interpretation of the analysis			
Used appropriate, reliable references that were accurately cited			
<b>The Justification</b>			
Explains why the evidence is important or why it is relevant			
Links the evidence to an important concept or principle			
<b>The Challenge</b>			
The alternative explanation(s) being challenged is (are) explicit			
Explains why the alternative explanation is inaccurate			
<b>Language of Science</b>			
Use of scientific terms is correct			
Used ecology terms from class			
<b>Mechanics</b>			
The order and arrangement of the sentences enhances the development of the main idea (organization)			
The author used complete sentences, proper subject-verb agreement, and kept the tense constant (grammar)			
The author used appropriate spelling, punctuation, and capitalization (conventions)			
<b>Total Score</b>	___/15		

APPENDIX D  
PRESENTATION 2

## **PRESENTATION 2 OUTLINE**

### **1. QUESTION**

Use the Oral Presentation Rubric as a guide and choose one of the following questions, or create your own:

- What conditions are required for life to exist in my biome jar?
- Why is the jar considered a biome?
- How do abiotic factors affect the biotic factors in the biome jar?
- Or, create your own question pertaining to conditions within your biome jar

### **2. CLAIM**

Provide an explanation relevant to the question (claim)

### **3. EVIDENCE**

Support your claim with evidence (include some observations you have made of your biome jar!)

### **4. JUSTIFICATION**

Explain how your evidence supports your claim (justification using ecological concepts) for help with justification make sure you are using the ecological and scientific terms provided in your learner goals page.

APPENDIX E  
WATER PROPERTIES ACTIVITY



## Water Properties Template

Participation in this activity will not affect your grade in any way.

Please enter your question regarding properties of water, your claim, evidence you provided to support your claim, and of justification of evidence that provides science concepts related to water properties that links your evidence to your claim

Please type your name here

### Question

Please type your essential question from your template here

### Claim

Please type your claim from your template here

### Evidence

Please type your evidence from your template here

### Justification

Please type your justification from your template here

Submit

*Never submit passwords through Google Forms.*

APPENDIX F  
PLANT BIOMASS ACTIVITY

## **PLANT BIOMASS WRITTEN ARGUMENT OUTLINE**

### **1. QUESTION**

Use the Written Argument Rubric as a guide to answer the question,

*Where does most of the matter that makes up the stem and leaves of a plant come from?*

### **2. CLAIM**

Choose one of the three provided explanations as your claim

Explanation 1: The matter that makes up the stem and leaves comes from the soil because it contains the minerals and food that a plant needs to survive.

Explanation 2: The matter that makes up the stem and leaves comes from the air because carbon dioxide is the source of carbon for plants.

Explanation 3: The matter that makes up the stem and leaves comes from water because water is used in photosynthesis.

### **3. EVIDENCE**

Support your claim with evidence (you are encouraged to use resources online)

### **4. JUSTIFICATION**

Explain how your evidence supports your claim (justification\_using ecological concepts) for help with justification make sure you are using the ecological and scientific terms provided in your learner goals page.

APPENDIX G  
WRITTEN ARGUMENTATION RUBRIC

## WRITTEN RUBRIC

Aspect of the Essay	Point Value		Comments or Suggestion
	0	1	
<b>The Question</b>			
The question is sufficient			
<b>The Claim</b>			
The claim that is being advanced is clear			
The claim that is being refuted (the misconception) is clear			
<b>The Evidence</b>			
Describes the evidence that supports the claim that is being advanced			
Describes the evidence as examples, applications, observations, rather than presented as sets of facts			
Interpretation of the literature is correct			
Used appropriate, reliable references that were accurately cited			
<b>The Justification</b>			
Explains why the evidence supporting the claim that is being advanced is important or relevant			
Links the evidence to important concepts or principles			
<b>The Challenge</b>			
Explains why the claim being refuted is inaccurate			
Explains how or why the misconception may have been developed			
<b>Language of Science</b>			
Use of scientific terms is correct			
Used ecology terms from class			
<b>Mechanics</b>			
The order and arrangement of the sentences enhances the development of the main idea (organization)			
The author used complete sentences, proper subject-verb agreement, and kept the tense constant (grammar)			
The author used appropriate spelling, punctuation, and capitalization (conventions)			
<b>Total Score</b>	___/15		

APPENDIX H  
FINAL PROJECT OUTLINE

**Final Project – Choose one of the following three choices and use both rubrics as guidelines to create both a written argument essay and an accompanying oral presentation:**

## Wild Bighorn Sheep: On the Edge?



This lesson was adapted from:

Lesson author:

Dr. Melissa Reynolds-Hogland, Bear Trust International

Copyright 2013:  
Wild Sheep

In this activity, you will use real-world data and information from case studies on three different herds of Rocky Mountain bighorn sheep that live in Montana. In a mock scenario, you will assume the role of a decision maker who has to determine which of the three herds face the most critical factors affecting their conservation. Obviously, there is a need and desire to help all three herds, but current budgets allow conservation biologist to help only one. Which one is in most dire need? That is for you to decide using evidence from the provided data.

## Where Will the Wood Bison Roam?



This lesson was adapted from:

Copyright 2012: Bear Trust International, Alaska Wildlife Conservation Center and Inspired Classroom

Lesson authors:

Dr. Melissa Reynolds-Hogland and Allison DePuy


There are currently no wood bison in the wild in the United States. In efforts to help conserve wild populations of wood bison in Alaska, wood bison biologists at the Alaska Department of Fish and Game are working to reintroduce a wood bison herd somewhere in the historic wood bison range in Alaska. Where exactly? Aha! This is for you to determine, based on data collected from each of three potential sites.

## Wolves and Elk in Yellowstone



In this activity, you will use real-world data and information gathered from the Internet to determine the effect of wolves on elk populations in and around Yellowstone National Park. Many people, sportsmen, hunters and cattle ranchers especially, contend that the introduction of wolves to the Greater Yellowstone Ecosystem has severely decreased the number of elk in the area. To them, that's a bad thing. Do you think these people are justified in their Conclusion? Use the following report to begin your investigation of this question. If a more interesting question arises, feel free to the answer that question instead.

APPENDIX I  
PRE-TREATMENT QUIZ



Edit this form

## Reasoning Skills Questionnaire

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

Please type your name here:

**"Grand Canyon National Park encompasses more than 1.2 million acres" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"There are seven days in a week" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"Koala bears are the cutest animals in Australia!" is**


- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"The Grand Canyon is considered the most visited tourist spot in the United States" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first

Note: The Pre-Treatment Reasoning Skills Quiz contained the same content as the Post-Treatment Reasoning Skills Quiz; the only difference was the design layout. Refer to Appendix J.

APPENDIX J  
POST-TREATMENT QUIZ



## Final Reasoning Skills Questionnaire

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

Please type your name here:

**"Grand Canyon National Park encompasses more than 1.2 million acres" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"There are seven days in a week" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"Koala bears are the cutest animals in Australia!" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

**"The Grand Canyon is considered the most visited tourist spot in the United States" is**

- a fact
- an opinion
- it might be a fact, but I'd have to verify it first
- none of the above

Regarding the best way to diaper a small baby, which source is the most credible:

- an elementary teacher
- a baby store owner
- a family counselor
- a mother of four

In defense of a girl accused of shoplifting, which source is the most credible:

- her mother
- her best friend
- a witness
- her teacher

You want to find out about the condition of a used car you are thinking of buying, which source would provide the most credible information:

- an independent car mechanic
- the used car salesperson
- the car's owner
- a friend who also likes the car

You want to find out about the quality of diamonds in a pawn shop, which source would provide the most credible information:

- a friend who shops there all the time
- the shop's owner
- a professional jeweler
- an antique dealer

"I have succeeded because I was destined to succeed."

- the speaker is presenting a piece of evidence
- the speaker is presenting an untestable explanation
- the speaker is presenting data
- the speaker is stating a observable fact

Place a check next to the following examples that you might use as EVIDENCE to support a claim:

check as many as apply

- personal opinions
- text from a science article
- background knowledge
- personal experiences
- data from a data table
- observations that another student made
- measurements
- a prediction
- notes you took during class
- something you saw in a movie
- an interview with an expert
- a hypothesis
- a chart or graph
- a photograph
- a drawing
- observations from an investigation you conducted
- your instinct
- anything you find online
- information from a peer reviewed study

Describe the rule you used for something to be considered EVIDENCE:

APPENDIX K  
SCIENTIFIC EXPLANATION RUBRIC



## Scientific Explanation

Scientific Explanation Rubric

Name

assignment name

Essential Question was provided or created

- Provided
- Created
- no question created

Claim

- Student did not make a claim
- Student made a claim but claim did not address question
- Student made a claim that addressed the question

Did student provide excess in claim?

Was their claim sufficient?

Claim clarity

was the claim clearly present

- yes
- it was there, but not initially clear
- no obvious claim provided
- claim was indistinguishable from evidence

Evidence

observational descriptions were encouraged

- Student did not provide evidence
- Student provided evidence but it did not support their claim
- Student provided evidence that supported their claim

What type of data/evidence was provided

choose all that apply

- personal observations
- material likely discussed in class
- obvious textbook or internet resources
- opinion

Justification/Reasoning

- Student provided no justification
- Student provided justification but did not link the evidence to the claim
- Student provided justification that linked the evidence to the claim

Validity of Justification/Reasoning

how scientifically accurate was the justification

- no justification was provided
- justification was scientifically incorrect
- justification was scientifically correct

APPENDIX L  
STUDENT INTERVIEW QUESTIONS

## Student Interview Questions

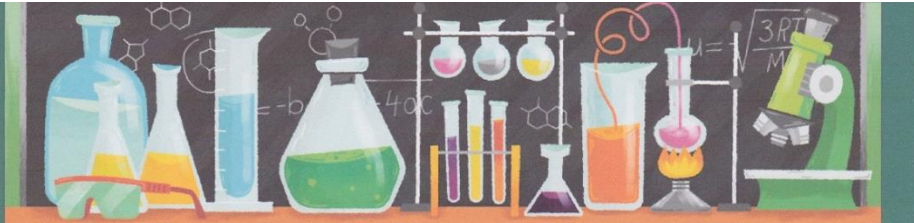
**READ TO STUDENT FIRST:** Participation in this research is voluntary and will not affect your grades or class standing in any way. Your name and all answers you provide will be kept anonymous, so please feel free to answer the following questions as honestly as you can.

**Are you ready to begin?**

1. What is your name?
  2. Before the ecology class you are in now, have you ever had to support a claim with evidence for a class assignment? If yes, explain.
  3. From your own experience, when you come up with a question to investigate, do the terms claim, evidence, and justification of evidence make sense to you or is it confusing? Explain.
  4. On a scale of 1 to 5, how important is it to provide evidence to support claims? 1 means not important and 5 means very important.
  5. Using the same scale, how important is it to provide justification for evidence used?
  6. Is there a difference between data and evidence? Explain
  7. Do you feel comfortable reviewing another classmate's idea?
  8. Do you feel comfortable sharing your ideas with the class as an individual?
  9. What does scientific argumentation mean to you?
  10. Do you think scientific argumentation is different than regular conversational arguments? Explain
- Is there anything else you would like me to know?

APPENDIX M

PRE-TREATMENT STUDENT SURVEY



## Student Survey

Please type your name here

### Instructions

Participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Answer the following questions honestly. A response of 1 means you strongly agree, 2 means you agree, 3 means you disagree, and 4 means you strongly disagree.

Thank you for your time!

*I can succeed in science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I am confident that I understand science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I can solve complex problems in science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*Science is too hard.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I can interpret data tables and graphs in science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I can create scientific explanations using evidence*

1 2 3 4

Strongly Agree     Strongly Disagree

*I understand the language of science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*Science is important.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I want to succeed in science.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I want to understand scientific concepts*

1 2 3 4

Strongly Agree     Strongly Disagree

*I think doing well in science is important.*

1 2 3 4

Strongly Agree     Strongly Disagree

*It is important to be able to create scientific explanations.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I feel comfortable commenting on other student's work.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I feel comfortable expressing my ideas on paper.*

1 2 3 4

Strongly Agree     Strongly Disagree

*Scientific argumentation is the same as regular conversational arguments.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I feel confident in my abilities to use evidence to support claims.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I am good at identifying valid evidence.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I know the difference between primary and secondary sources of data.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I have experience in writing arguments with supporting evidence.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I am concerned I will hurt another student's feelings if I disagree with them.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I feel safe speaking my thoughts in my science class.*

1 2 3 4

Strongly Agree     Strongly Disagree

*I feel comfortable sharing my ideas with a small group.*

1 2 3 4

Strongly Agree     Strongly Disagree

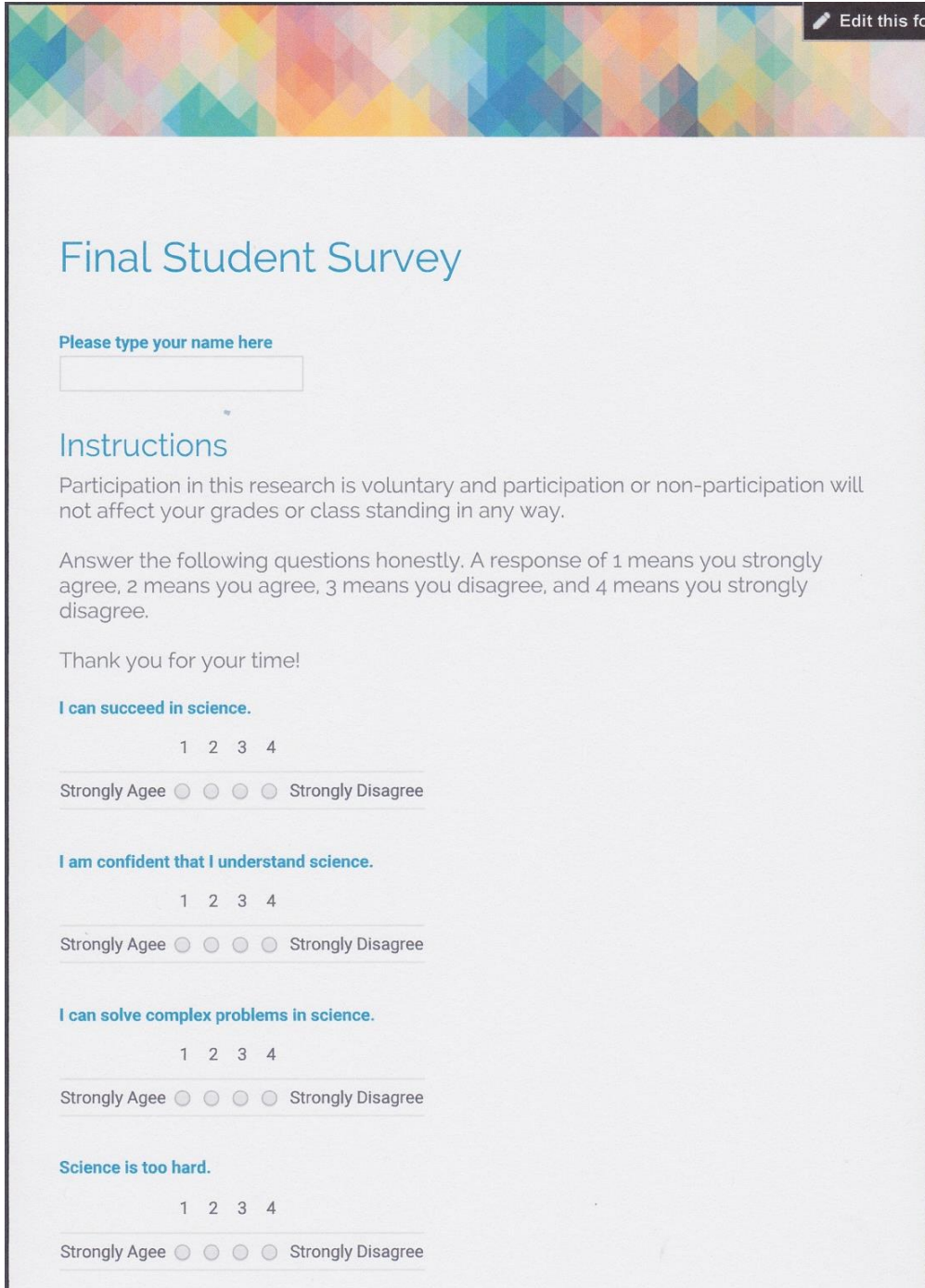
*I consider myself a leader in small groups.*

1 2 3 4

Strongly Agree     Strongly Disagree

*In your own words, define scientific argumentation.*

APPENDIX N  
POST-TREATMENT STUDENT SURVEY



Edit this fo

## Final Student Survey

Please type your name here

### Instructions

Participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way.

Answer the following questions honestly. A response of 1 means you strongly agree, 2 means you agree, 3 means you disagree, and 4 means you strongly disagree.

Thank you for your time!

**I can succeed in science.**

1 2 3 4

Strongly Agree     Strongly Disagree

**I am confident that I understand science.**

1 2 3 4

Strongly Agree     Strongly Disagree

**I can solve complex problems in science.**

1 2 3 4

Strongly Agree     Strongly Disagree

**Science is too hard.**

1 2 3 4

Strongly Agree     Strongly Disagree

Note: The Post-Treatment Student Survey contained the same content as the Pre-Treatment Student Survey; the only difference was the design layout. Refer to Appendix L