

Scientific Explanations
Peer Feedback or Teacher Feedback

by

Katie Lange

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Arts

Approved June 2011 by the
Graduate Supervisory Committee:

Dale Baker, Chair
Colleen Megowan
James Middleton

ARIZONA STATE UNIVERSITY

August 2011

ABSTRACT

Writing scientific explanations is increasingly important, and today's students must have the ability to navigate the writing process to create a persuasive scientific explanation. One aspect of the writing process is receiving feedback before submitting a final draft. This study examined whether middle school students benefit more in the writing process from receiving peer feedback or teacher feedback on rough drafts of scientific explanations. The study also looked at whether males and females reacted differently to the treatment groups. And it examined if content knowledge and the written scientific explanations were correlated.

The study looked at 38 sixth and seventh-grade students throughout a 7-week earth science unit on earth systems. The unit had six lessons. One lesson introduced the students to writing scientific explanations, and the other five were inquiry-based content lessons. They wrote four scientific explanations throughout the unit of study and received feedback on all four rough drafts. The sixth-graders received teacher feedback on each explanation and the seventh-graders received peer-feedback after learning how to give constructive feedback. The students also took a multiple-choice pretest/posttest to evaluate content knowledge.

The analyses showed that there was no significant difference between the group receiving peer feedback and the group receiving teacher feedback on the final drafts of the scientific explanations. There was, however, a significant effect of practice on the scores of the scientific explanations.

Students wrote significantly better with each subsequent scientific explanation. There was no significant difference between males and females based on the treatment they received. There was a significant correlation between the gain in pretest to posttest scores and the scientific explanations and a significant correlation between the posttest scores and the scientific explanations. Content knowledge and written scientific explanations are related. Students who wrote scientific explanations had significant gains in content knowledge.

ACKNOWLEDGMENTS

I would like to thank Dr. Dale Baker, Dr. James Middleton and Dr. Colleen Megowan for their guidance, assistance, and direction in completing this thesis. Without your help I would have been completely lost. It has been your invaluable contributions that have made this paper a success. I would especially like to thank Dr. Baker as my advisor for all of your time and effort in guiding me through not only the thesis process, but also for your guidance and support throughout this entire program. I truly learned a great deal from you in class and in writing this thesis.

I also wish to thank the faculty and students of Emmanuel Lutheran School. It was your encouragement that pushed me to start the program at Arizona State University. I appreciate your support throughout the program in helping relieve some of my load at school so that I could be a successful student.

Special thanks go to my fellow students who helped me in so many ways. In particular, Melissa Melville and Ashley Tillman became far more than just fellow students. They became true friends. Thank you ladies for your help and support. Without you I would have never made it through this program. Finally, I would like to thank my family for their continued encouragement these past two years. It means a great deal to me that you believe in me so much.

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	vi
LIST OF FIGURES.....	vii
PREFACE.....	viii
CHAPTER	
1 INTRODUCTION.....	1
Research Questions.....	4
2 LITERATURE REVIEW.....	6
Scientific Literacy.....	6
Science as a Socially-Driven Discipline.....	8
Content Knowledge and Scientific Explanations.....	11
Teacher Feedback.....	12
Peer Feedback.....	13
3 METHODS.....	17
Study Participants.....	17
Experimental Design.....	17
Unit of Instruction.....	19
Instrumentation.....	22
4 DATA ANALYSIS.....	24
Data Analysis by Research Question.....	24
5 RESULTS.....	27
Question One.....	27

	Page
Question Two	28
Question Three	29
Question Four	31
Question Five.....	35
6 DISCUSSION AND IMPLICATIONS	38
Future Research.....	40
Limitations	41
REFERENCES	45
APPENDIX	
A BASE EXPLANATION RUBRIC	48
B SURVEY QUESTIONS	50
C UNIT OF INSTRUCTION	52
D PRETEST/POSTTEST	66
E. SAMPLES OF STUDENT WRITING.....	72

LIST OF TABLES

Table		Page
1.	Demographics of participants	17
2.	Descriptions of the lessons and questions in the Earth Systems unit	22
3.	Average scores out of a possible 9 points on scientific explanations between teacher review and peer review groups	27
4.	Results of univariate analysis of variance	28
5.	Average scores on scientific explanations out of a possible 9 points of female and male students receiving teacher feedback and peer feedback	29
6.	General linear model of repeated measures	30
7.	Average score on each explanation by review group out of a possible 9 points	31
8.	Tests of within-subjects contrasts using a general linear model.....	32
9.	Average scores out of a possible 20 on pretest and posttest and average gain with standard deviation from pretest to posttest by review group	32
10.	Pearson correlations between scientific explanation scores and posttest	33
11.	Pearson correlations between scientific explanation scores and posttest	34

LIST OF FIGURES

Figure	Page
1. Components of scientific reasoning and science literacy	7
2. The tools of science needed to produce scientific explanations	10
3. Percentage of posttest score that can be explained by the writing of the scientific explanations	34
4. Percentage of gain score that can be explained by the writing of the scientific explanations	35

Chapter 1

INTRODUCTION

Writing scientific explanations is a time-intensive process that includes writing a rough draft, making multiple revisions, receiving feedback from others and finally writing the final draft. The step of receiving feedback is invaluable to the entire process. The purpose of this study is to examine the effectiveness of teacher feedback and peer feedback on written scientific explanations of students in sixth and seventh-grade earth science. More specifically, the researcher was concerned with the difference between the achievement of students on the scientific explanation when receiving teacher feedback versus the students receiving peer feedback. The study also examined the relationship between the type of feedback and the variable of gender. The researcher also examined the difference between the gain of content knowledge based on the pretest and posttest scores when receiving peer feedback versus teacher feedback on scientific explanations. Finally a survey was conducted after the unit of instruction to obtain students perceptions about the quality of the feedback and the usefulness of giving and receiving feedback based on which group they were in.

The ultimate goal of K-12 science education is that all students should become scientifically literate citizens in today's science-infused world (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). With the decisions facing people in this global age, "everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology" (NRC, p. 1, 1996).

Typically in school we emphasize the 3 R's, reading, writing, arithmetic (Zimmerman, 2000). This has never been truer than with the high-stakes testing era that we have recently entered. In order to pass the standardized tests, teachers feel they must go back to the basics and emphasize the knowledge found on the tests. Unfortunately in doing this, we are depriving our students of developing the problem-solving and reasoning skills they will need to succeed in the future. In order to develop these skills that our students must have, we need to give them opportunities to engage in scientific inquiry. Scientific inquiry involves both problem solving and reasoning, skills not taught in the other traditional subjects of reading, writing and arithmetic (Zimmerman, 2000).

The *National Science Education Standards* (NRC, 1996) emphasize engaging students in inquiry activities including the construction of scientific explanations in K-12 science classrooms because it involves the joint development of scientific knowledge and reasoning and thinking skills.

“When engaging in inquiry, students describe objects and events, ask questions, **construct explanations** [emphasis added], test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this ways students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills” (NRC, p. 2, 1996).

The practice of creating and specifically writing scientific explanations is a key component of scientific literacy and one of the most critical skills in developing scientific reasoning. According to McNeill, Lizotte, Krajcik, and Marx (2006) scientific explanations tell how or why something happened. This type of inquiry is known as argumentation where students are able to explore how

they know what they know by collecting evidence, critically evaluating the evidence, and constructing explanations (also known as arguments) based on the data (Osborne, 2010). Scientific explanations are based on the Toulmin model and have a structure of claim, evidence and reasoning (Toulmin, 1958). A claim is a statement that answers the question or problem that students are investigating. Evidence is the data, qualitative and/or quantitative, that supports the claim. Reasoning requires students to apply and use ideas of the larger conceptual framework of science to explain the phenomena and show why their data count as evidence and how they connect to the claim (Novak, McNeill, & Krajcik, 2009).

The use of written feedback on scientific explanations is one avenue for students to deepen their conceptual knowledge of science and scientific explanations. Konold, Miller and Konold (2004) found that feedback plays a critical role in learning and that written feedback from the teacher can improve the performance of *all* students. Teachers are a crucial source of external feedback because they are more effective in identifying mistakes and misconceptions than peers (Nicol & Macfarlane-Dick, 2006). However many studies have shown that providing students with the opportunity to read and evaluate scientific texts is an extremely valuable practice to improve scientific literacy.

In order to publish new scientific research, scientists will submit their work to peers to decide whether the paper is acceptable and ready to be published. Since the scientific community regularly does peer evaluations of scientific explanations, it is logical that science classes should emphasize the process as

well (Venables & Summit, 2003). Peer review provides students with the opportunity to consider the worth and value of other students' work, and it exposes them to a wide variety of thinking and it helps students develop a critical eye (Venables & Summit, 2003). Peer assessment is also learning by doing which improves understanding of the structure of scientific explanations. When students are exposed repeatedly to the structure of scientific explanation in a variety of ways, they will be able to write a better explanation themselves.

Research Questions

1. What are the differences in the overall achievement levels on scientific explanations between students who receive teacher feedback and students who receive peer feedback during the writing process?
2. What differences in achievement levels of the scientific explanations constructed by students exist by gender in peer feedback or teacher feedback groups?
3. What was the difference in the scientific explanations over time between students who receive teacher feedback and students who receive peer feedback during the writing process?
4. What was the difference between the gain of content knowledge based on the pretest and posttest scores when receiving peer feedback versus teacher feedback on scientific explanations?
5. What did the students perceive about the quality of the feedback and the usefulness of giving and receiving feedback based on which group they were in?

Chapter 2

LITERATURE REVIEW

Scientific Literacy

The *National Science Education Standards* [NSES] (NRC, 1996) and the *American Advancement for the Achievement of Science* (AAAS, 1993) have a goal of scientific literacy for all Americans. Traditionally scientific literacy emphasized understanding the concepts and processes (e.g., observing, inferring, predicting...) of science so that citizen can make informed decisions in personal and social issues (Cavagnetto, 2010). However, the skills required for creating scientific explanations are increasingly being emphasized in science education because integrating the skills and concepts of science supports true scientific literacy.

The ability to create scientific explanations is one of the most essential skills defining scientific thinking. It combines a number of complex skills including the ability to articulate a theory, to understand the type of evidence that could support or contradict that theory, and to justify the selection of one of the competing theories that explain the same phenomenon (Zimmerman, 2000). Cavagnatto (2010) has suggested that students who engage in argumentation develop communication skills, metacognitive awareness, critical thinking, and an understanding of the culture and nature of science. Metacognitive awareness and self-monitoring promote meaningful learning by enabling students to effectively assess their understanding of a subject and learn more deeply (Armstrong, Wallace, & Chang, 2007; Chin & Brown, 1999). Students who use metacognition

and self-monitoring to create explanations are far more likely to have meaningful conceptual knowledge (Chin & Brown, 1999).

It is important then to teach science not only as a content domain but also as an academic skill of scientific reasoning in which students create scientific explanations (Zimmerman, 2000). When the skills of argumentation and the concepts of science are taught together, the interaction of the skills and concepts should “bootstrap” each other. As Figure 1 shows, students with greater content knowledge will better refine scientific explanations, and students with a greater ability to scientifically explain phenomena will build greater content knowledge. Since scientific literacy is a mix of content, and explanation learned through inquiry, we should figure out how to make argumentation a central feature of school science (Yore, Hand, Goldman, Heldebrand, Osborne, Treagust, & Wallace, 2004).

Figure 1. Components of Scientific Reasoning and Science Literacy

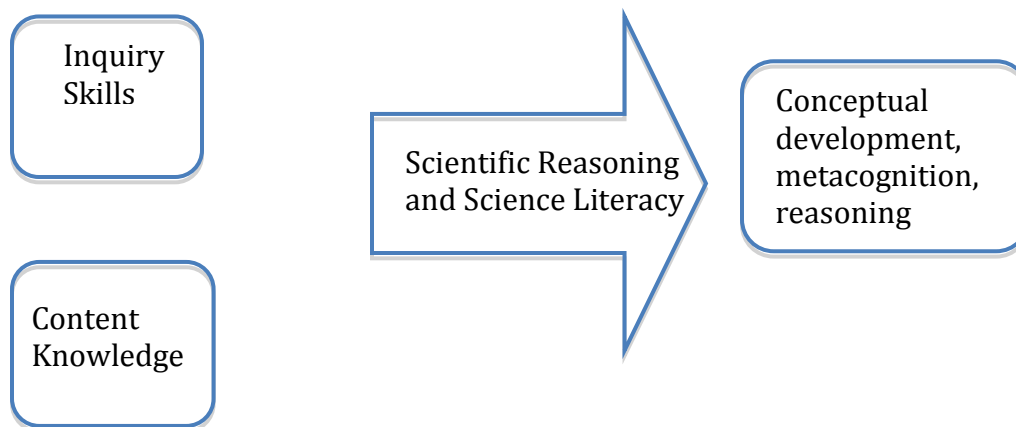


Figure 1 shows necessary components to produce a written scientific explanation. Inquiry and content knowledge “bootstrap” each other to support scientific reasoning and science literacy.

“Rarely are students able to explore how we know what we know, how such knowledge came to be, or why it matters” (Osborne, p. 62, 2010). The use of language and writing serves this exploration and learning by facilitating conceptual organization and restructuring, metacognitive awareness, critical reasoning, and higher order thinking skills (Cavagnatto, 2009; Hand & Prain, 2002; Keys, 1999; Osborn, 2010; Wallace, 2004; Yore et. al, 2004; Zembal-Saul, 2008). Writing scientific explanations, therefore, is an important exercise for our students to engage in on a regular basis. A scientifically literate person can understand and apply the fundamental elements of scientific explanation which include claim, evidence, and reasoning (Wallace, 2004). A claim is a statement that answers the question or problem that students are investigating. Evidence is the data, qualitative and/or quantitative, that supports the claim. Reasoning requires students to apply and use scientific ideas to explain the phenomena and show why their data count as evidence and how they connect to the claim (Novak, McNeill, & Krajcik, 2009).

However students struggle with scientific explanations because they lack understanding of the goals and processes of it. They can observe, but not explain. They struggle connecting the evidence to the claim through reasoning. Curriculum therefore should be designed to promote scientific explanation and must emphasize *how science knows* in addition to *what science knows*. It must have instructional strategies designed to support writing scientific explanations and needs to provide opportunities for students to evaluate and critique the processes, contexts, and products of inquiry (Sampson & Clark, 2008).

Science as a Socially-Driven Discipline

Science is an inquiry-based discipline in which scientists are actively searching for answers to the questions they have and then putting forth explanations of the observed phenomena for the scientific community to critique, revise and ultimately accept or reject. The knowledge of the scientific community is based on argumentation and these include developing taxonomies, laws, mathematical formulas and explanations (Newton, Driver, & Osborne, 1999). This model, however, is not the way that science has been traditionally been taught in school. The paradigm that continues to reign in school science is the transmission model of knowledge, whereby the teacher transmits the expert knowledge from themselves and the textbook into the knowledge base of the students through lectures, reading and a possibly some teacher demonstrations reinforcing the facts.

Teaching very often uses tools that are abstract and do not resemble the practices of real scientists. Students need to experience the authentic activities, which those in the science culture engage in order to go from novice to expert. Learning is a process of enculturation where the learners utilize the concepts and tools of scientists appropriate to their level of maturity slowly developing more sophisticated skills of an expert (Brown, Collins, & Duguid, 1989). Conceptual knowledge can be thought of as similar to a set of tools. Tools share significant features with knowledge: “They can only be fully understood through use, and using them entails both changing the user’s view of the world and adopting the belief system of the culture in which they are used” (Brown, et. al, pg 33, 1989).

As Figure 2 shows, these tools that scientists use include critical thinking, metacognition, self-monitoring and peer evaluation.

Figure 2 The Tools of Science Needed to Produce Scientific Explanations

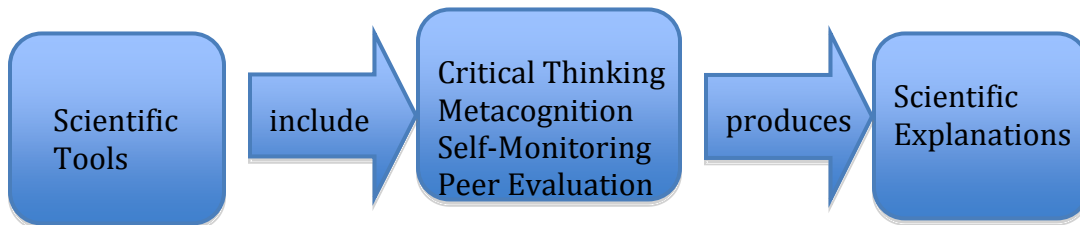


Figure 2 shows some of the tools that students need in order to successfully create a scientific explanation. Students must think critically in order to accept or reject data to support the claims they make. Metacognition is necessary in order for students to be aware of their own understanding and to control and manipulate their own cognitive processes. Self-monitoring is the ability of students to monitor and adjust their learning based on feedback they receive. Students receive an outside perspective on their learning through peer evaluation.

Science education needs to be more than the transmission model and the individual mind learning facts. We should strive to incorporate more of the social constructivist and situative perspective in which society and culture produce the learning and students are engaged in the practices of real scientists (Newton, et. al, 1999). “Learning is a generative process requiring effort in which learners actively construct their own meanings that are consistent with their prior ideas rather than passively acquire knowledge transmitted to them” (Chin & Brown, p. 110, 1999).

Creating scientific explanations meets the needs of this cognitive development because it is socially driven, language dependent, governed by context or situation, and involves a variety of tool-use and cognitive strategies (Osborne, Erduran, & Simon, 2004). Students need opportunities to externalize explanations and to hold up their beliefs and their justification for inspection by others (Osborne, et. al, 2004). The importance of explanation to education is rooted in the concept that learning takes place as a result of social interactions in which participants collaboratively develop conceptual knowledge (Vygotsky, 1978).

There is agreement that students need to construct their own conceptions of science and find meaning individually and within a social community and accepted science (Keys, et. al, 1999). Teachers need to create rich learning environments where students can talk about science (Akkus, Gunnel, & Hand, 2007). Students need to practice creating explanations themselves to become part of the scientific community (Newton et. al, 1999).

Content Knowledge and Scientific Explanations

Research has shown that feedback on written scientific explanations helps deepen students' conceptual knowledge. Akkus et al. (2007) found that an emphasis on the collaborative and constructive nature of scientific activity, specifically scientific explanation, significantly increased content knowledge. They had seven teachers who taught different science subjects from grades 7-11 divide his/her classes into either traditional teaching approach (control) or the Science Writing Heuristic (SWH) approach (treatment). The teachers attended a

2-day workshop on the implementation of the SWH, which is a template for student thinking that “prompts learners to generate questions, claims, and evidence for making an argument based on valid reasoning” (Akkus et al., pg. 1746, 2007). The students were placed into high or low-achieving groups with the use of a baseline test. After the study, students in the SWH groups scored significantly higher on the multiple-choice posttest than students in the traditional groups. The low-achieving students performed much better when they did not have to “play the memory games generally associated with traditional teaching, [and] performed much better when the focus was on conceptual understanding” (Akkus et al., pgs. 1762-1763, 2007).

McNeill et al. (2006) also found a relationship between content knowledge and scientific explanations. They conducted a study with 331 seventh-grade students. The students were placed into two groups: continuous scaffolding and faded scaffolding. The continuous scaffold group received the same scaffold on three scientific explanations while the faded scaffold group received less of a scaffold on each explanation. By the end they only received the words: claim, evidence, and reasoning. Students in both groups had significant pretest to posttest gains. There was a significant correlation between students’ posttest and explanation scores. The students who had higher multiple-choice scores also had higher explanation scores.

Teacher Feedback

In general feedback is seen as the responsibility of the teacher (Nicol & Macfarlane-Dick, 2006). Students look to the teacher as a reliable source of

knowledge able to provide guidance and direction when making revisions in writing scientific explanations. Students therefore may be more receptive to feedback from the teacher because the teacher should be guiding them to the correct answer. Teachers are also more likely to identify mistakes. Nicol and Macfarlane-Dick (2006) found that teachers were a crucial source of external feedback because they were more effective in identifying mistakes and misconceptions than peers.

Konold, Miller and Konold (2004) found that feedback played a critical role in learning and that written feedback from the teacher improved the performance of *all* students. The feedback needs to be specific, appropriate, high quality, timely, accurate, constructive, outcome-focused, encouraging, positive, understandable and focused on what is done correctly and what needs to improve (Konold et al., 2004).

Peer Feedback

Science is a socially-driven discipline in which arguments, theories, laws and explanations are accepted or rejected based on peer review. The scientific community ultimately determines what we know as scientific knowledge. Since we want students to be enculturated into science and use the tools of science we need to give students an avenue to engage in the use of these tools. Providing and receiving feedback on scientific explanations is one such avenue for students.

While teacher guidance is important in effective learning, to truly embrace a social-constructivist perspective of learning students should participate in peer review. The social construction of knowledge through scientific explanations

happens in peer group discussions and peer writing evaluation. It promotes thinking about the audience and deepening elaborations and connections in the writing (Keys, et. al, 1999). “Such peer processes help develop the skills needed to make objective judgments against standards, skills which are transferred when students turn to producing and regulating their own work” (Nicol & MacFarlane-Dick, p. 208, 2006). Students need to reevaluate and refine the concepts they are writing about. Students need to know what good performance is, how their performance compares and how they can close the gap between what is desired and what is reality (Nicol & MacFarlane-Dick, 2006).

Many studies have shown that providing students with the opportunity to read and evaluate scientific texts was an extremely valuable practice to improve scientific literacy (Venables & Summit, 2003). Having students engage in evaluating explanations for scientific evidence was a significant learning activity, which promoted cognitive and affective outcomes (Yore, et al., 2004). Peer review provided students with the opportunity to consider the worth and value of other students’ work and it exposed them to a wide variety of thinking and it helped students develop a critical eye (Venables & Summit, 2003). Nicol and Macfarlane-Dick (2006) found that peer dialogue enhanced students’ sense of self-control over their learning for 5 reasons. 1) students who have just recently learned the material are often able to explain the concept in a more accessible way to struggling students. 2) peer discussion promotes alternative perspectives to problems. 3) when students comment on each other’s work they develop a detachment to the work and can then assess their own work better. 4) peer

discussion can encourage students to be persistent. 5) it is sometimes easier for students to accept criticism from a peer.

It is important for students to write for an audience other than the teacher. Students write less for the teacher because they know the teacher has the background to interpret the explanation without great detail (Wallace, 2004). Because students may elaborate their explanations for audiences other than the teacher, students need access to communication with peers to develop authenticity in their scientific language (Wallace, 2004).

Young people's judgments are highly influenced by their peers, and peer groups provide powerful motivation to do well. Students who engage in peer review have a more positive attitude toward writing. Students whose work was peer evaluated as compared to teacher evaluation were more likely to share their writing, read classmates' papers and offer advice, and rewrite. Overall, they thought their writing was improving. (Katstra, Tollefson, & Gilbert, 2001). This may be because students are allowed to give feedback without constraints, exploring their ideas without fear or criticism from the teacher (Rivard, 2003).

Jensen and Fischer (2005) found an increase in student learning as a result of peer evaluation in two college-level science courses. All students wrote three lab reports. In the experimental group, the first two lab reports were peer evaluated and the third was teacher evaluated. In the control group, the teacher evaluated all three. The experimental group had a higher class average on all three reports. Course evaluations showed that the students felt the process of evaluating peers

greatly enhanced their personal writing abilities by providing insight on methods or techniques they could use in their own writing.

Peer discussion and feedback may benefit some students more than others. Rivard conducted a study with 8th graders. He had a control group who were given restricted writing activities and an experimental group who wrote science explanations. The experimental group was placed into three different treatment groups: talk-only, talk-write, write-only. Only the write-only group worked individually. The talk-only and talk-write group utilized peer discussion in creating explanations. All students were further disaggregated into low, average and high achieving based on past achievement level in 7th grade science.

The high achieving students made gains in all four groups, but they had the largest gains on the posttest in the write-only group. The average and low achievers had the largest gains in the talk-only groups. However, on a delayed posttest, the talk-write group's score surpassed that of the talk-only group. Low achievers benefitted the most from collaboration, but it is important to note that average and high-achievers still benefitted from peer support (Rivard, 2003).

Science literacy for all students is a lofty goal. It is more important than ever to increase our students' scientific reasoning and content knowledge not only to make informed decisions in personal and social issues but to also scientifically explain the reasons behind the decision. The use of peer review process is an important tool for scientists when accepting or rejecting science explanations, so it is important to look at the effects of the peer and teacher feedback on students' explanations.

Chapter 3

METHODS

Study Participants

Subjects in this study were sixth (N=19) and seventh (N=19) graders in two classes at Emmanuel Lutheran School in Tempe, Arizona. The students were all in earth science during the 2010-2011 school year with the same science teacher. The students' socioeconomic backgrounds are diverse ranging from low to middle-high. There were 25 females and 13 males in the study. Over half of the students (N=27) are Caucasian, and the other students come from ethnically diverse backgrounds with 5 American Indian, 4 Hispanic, 1 African-American, and 1 Pacific Islander.

Table 1
Demographics of Participants

Grade Level	Number of Students	Females	Males	Caucasian	American Indian	Hispanic	Pacific Islander	African American
6	19	12	7	13	3	2	1	0
7	19	13	6	14	2	2	0	1
Total	38	25	13	27	5	4	1	1

Experimental Design

The research followed a quasi-experimental design because the students were not assigned to the experimental groups randomly. The two groups were already set based on which class they were in, sixth or seventh. The research was conducted between participants because each student only received one of the two treatments. The classes were put into two different treatments: peer feedback or

teacher feedback. The sixth graders received teacher feedback on rough drafts of scientific explanations and the seventh graders received peer feedback.

Because the groups were already set, a pretest was given to determine if both classes had a similar content-knowledge base. The pretest was a two-tiered multiple-choice test designed to determine students' prior content knowledge of earth systems. The same test was also administered at the end to see if there was a significant difference in total gain of content knowledge between the two classes due to the different treatment they received.

During the instruction on the earth systems unit, the students were asked to write four different scientific explanations related to the topics studied. After completing the rough draft, the sixth graders received teacher feedback, and the seventh graders received feedback from two peers. Both groups had the same amount of time during class to work on the scientific explanations. The teacher evaluated the final drafts of the scientific explanations using the base explanation rubric that all students received in the first lesson of the unit, and a score was given with a point range of 3-9.

After the completion of the unit, an oral survey was administered by the principal to all of the students who participated in the study in groups of three or four. He took the groups over a span of two days. He asked the groups 8 questions. The questions were designed to gain an understanding of how the students felt about receiving the feedback, if they would have preferred receiving feedback in a different way, if they used the feedback they received when making revisions. See appendix B for a complete listing of the questions. The survey

took 5-10 minutes depending on the group. He recorded notes of the student responses on the actual survey.

Unit of Instruction

The students received seven weeks of instruction on a unit on the earth systems: hydrosphere, geosphere, biosphere and atmosphere. The unit had six main lessons with one lesson at the beginning of the unit on writing scientific explanations. The larger conceptual framework of the unit was Earth is a complex system of interacting rock, water, air and life, and all lessons were designed to emphasize that idea. The larger conceptual framework for the unit was taken from Earth Science Literacy Principles: “Big Idea 3. Earth is a complex system of interacting rock, water, air, and life”, and all of the lessons were designed to tie into that framework (www.earthscineliteracy.org). The unit had lessons on the water cycle, the interaction between the systems in the wetlands, the atmosphere, and the sun and its power. The geosphere had been taught earlier in the year, but it was reviewed during this unit. Table 2 has a list of the lessons. The researcher designed the lessons based on the McRel standards (Kendall and Marzano, 2004), which were adopted by the school, and the lessons were supported by the National Science Education Standards (NRC, 1996).

All of the lessons utilized the 5 E instructional model. This model includes the following phases: engage, explore, explain, elaborate and evaluate. The National Research Council report *America’s Lab Report: Investigations in High School Science* (2006) calls for students who are engaged in forming their own questions, designing and conducting experiments, and constructing

explanations as they carry out investigations. The 5 E model meets all of those ideas set forth by the report. It is an inquiry-based approach to science that allows students to engage in experimentation while developing content knowledge and scientific reasoning skills (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook, Landes, 2006). The evaluate phase in four of the lessons was writing a scientific explanation.

At the beginning of the unit, the students all had a lesson on writing scientific explanations to prepare them for the upcoming unit in which they were asked to write four scientific explanations. Table 2 has a list of the questions on which the students had to write a scientific explanation. In the first lesson, students were given a copy of the base explanation rubric for their science notebooks which was kept throughout the unit and used both to give feedback on the rough drafts and used by the teacher to evaluate the final drafts. The students were taught how to understand and utilize the rubric for scientific explanations. They were also given the Argument Prompts from the IDEAS pack (Osborne, Erduran and Simon, 2004b) that they could use when giving and receiving feedback. The prompts included questions such as:

- Why do you think that?
- Can you think of another argument for that?
- How do you know?

The students in both classes had practice in evaluating and using both tools on simple scientific explanations during this lesson. They evaluated two different teacher-prepared explanations and spent 15 minutes in class discussing

what comments they could make to specifically help the student improve the explanation.

In all but one lesson, students were given a question to investigate, and then they engaged in inquiry activities designed to allow students to actively and socially construct a correct scientific explanation to answer the question. Students conducted experiments in groups of 3 or 4, which gave them the opportunity to engage in peer discussion prior to writing the scientific explanation.

At the end of four of the lessons students were asked to write a rough draft of a science explanation based on a question they were given at the beginning of the lesson. They incorporated the experiments and research they had conducted during the lesson. The topic of each lesson and the accompanying prompts are found in Table 2 below.

After completing the rough draft, the sixth graders received teacher feedback and then time to complete the final draft in class. The teacher utilized the base explanation rubric and the Argument Prompts from the Ideas Pack (Osborne et al., 2004b) to give each student specific feedback. Each student received a completed rubric with a grade that they would receive if that explanation were the final draft. They also had between three to five specific comments or questions written on the rough draft to give them guidance in completing the final draft. Very often the comments asked for more details on the experiments done in class or suggestions on how to tie in the larger conceptual framework.

The seventh graders had a mini lesson specific to each topic on how to evaluate a peer’s writing and then they received peer feedback from two classmates and made revisions either during the rest of the class period or at home. The peers also utilized the base explanation rubric and Argument Prompts (Osborne et al., 2004b) for each draft they read and made specific comments on the rough draft.

Table 2

Description of the lessons and questions in the Earth Systems unit

Earth Systems Unit	
Lessons	Science Explanation Question/Prompt
Lesson One: The structure of scientific explanations	Non-explanation lesson
Lesson Two: Introduction of Earth Systems: Geosphere and Hydrosphere	Did the water disappear after the rain? Where did the water go?
Lesson Three: Wetlands	Should we restore the wetlands?
Lesson Four: The Atmosphere	What makes up the atmosphere and how does that help living things stay alive
Lesson Five: Layers of the atmosphere	Non-explanation lesson
Lesson Six: The Sun and it’s Power	What is the role of the sun in powering the earth systems?

Instrumentation

Students were assessed before, during and after the earth systems unit with several instruments.

Earth Systems Content Knowledge. The pretest/posttest was a two-tiered multiple-choice test designed by the researcher to determine students' prior knowledge on the topics related to earth systems. There were 20 questions total; however, there were 10 question pairs since it was a two-tiered test. The odd numbered questions in the pair were fact/recall questions and the even numbered questions were higher order thinking questions getting at the reasoning behind the concept presented. The test had content validity because the content of the questions were aligned with the McRel standards (Kendall and Marzano, 2004) adopted by the school.

Because the test was created specifically for this unit, reliability was determined after the unit was taught and the posttest was scored. The test had low reliability with a Cronbach's Alpha score of .629. This could simply be due to the fact that the score was based off of a small number of test items, ten. A larger base of questions may have produced a higher reliability score.

Scientific Explanation Writing Skills. The students' writing skills were evaluated using McNeill and Krajcik's (2008) generic base explanation rubric. The rubric evaluated the three main parts of a scientific explanation: claim, evidence and reasoning. Each part received a score of 1, 2, or 3 for a total score of 9. All three parts were weighted equally in the final score.

Chapter 4

DATA ANALYSIS

Both quantitative and qualitative data were collected in this study.

Quantitative data were obtained through the use of the pretest/posttest and the base explanation rubric. Qualitative data came from the survey the students participated in after the completion of the unit. 6th graders all received teacher review and 7th grade all received peer review; therefore the data was analyzed using the class as the unit of analysis rather than the individual students. All of this data was analyzed in a number of ways in order to answer the questions put forth in the study.

Data Analysis by Research Question

1. What are the differences in the overall achievement levels on scientific explanations between students who receive teacher feedback and students who receive peer feedback during the writing process?

Students wrote four scientific explanations during the Earth Systems unit. Based on which class they were in, they either received peer feedback or teacher feedback on all four explanations. The teacher used the base explanation rubric on all final scientific explanations to give each explanation a score between 3 and 9 points. The four scores were totaled giving the student a total score between 12 and 36 points for the unit. A *t-test* determined if there was a significant difference for the scientific explanations between the teacher-reviewed and peer-reviewed explanations.

2. What differences in achievement levels of the scientific explanations constructed by students exist by gender in peer feedback or teacher feedback groups?

A univariate analysis of variance (ANOVA) was used to answer question 2 in order to see if there was a main effect between gender and reviewer (peer or teacher).

3. What was the difference in the scientific explanations over time between students who receive teacher feedback and students who receive peer feedback during the writing process?

A general linear model of repeated measures was used to answer question 3. The analysis was set with the score on each explanation over time as within-subjects factors and the treatment of reviewer as the between-subjects factors. This analysis determined whether the factor of time and experience made a difference in the scores of the scientific explanations between groups as a result of peers gaining more experience in giving feedback with each explanation.

4. What was the difference between the gain of content knowledge based on the pretest and posttest scores when receiving peer feedback versus teacher feedback on scientific explanations?

A general linear model of repeated measures was used to answer question 4. The analysis was set with the pretest and posttest as within-subjects factors and the treatment of reviewer as the between-subjects factors. The scores for the pretest and posttest were analyzed based on peer review or teacher review on scientific explanations to determine if there was any significant effect on the gain

of the content knowledge from pretest to posttest. Two Pearson correlations were also run to determine the relation between writing the science explanations during the lessons and the score on the pretest and posttest and then to determine the relationship between the explanations and the gain score from pretest to posttest.

5. What did the students perceive about the quality of the feedback and the usefulness of giving and receiving feedback based on which group they were in?

The survey responses were analyzed by grouping similar responses together in order to determine if there were any similarities in student replies.

Chapter 5

RESULTS

The students received peer review or teacher review on their scientific explanations. The results of the analysis are presented below question by question.

Question One

What are the differences in the achievement levels on scientific explanations between students who receive teacher feedback and students who receive peer feedback during the writing process?

No significant difference was found between the achievement levels on scientific explanations between students who received teacher feedback and students who receive peer feedback during the writing process. The scores are found on Table 3.

Table 3

Average scores out of a possible 9 points on scientific explanations between teacher review and peer review groups

Average Score and Standard Deviation on Scientific Explanation for 6 th grade: Teacher Review	Average Score and Standard Deviation on Scientific Explanation for 7 th grade: Peer Review	Results of <i>t</i> -test
8.08 out of a possible 9	7.96 out of a possible 9	$p = 0.67$
Standard Deviation = 3.2	Standard Deviation= 3.6	t ratio = .438

Question Two

What differences in achievement levels of the scientific explanations constructed by students exist by gender in peer feedback or teacher feedback groups?

The ANOVA looked at several variables. Those variables were gender and reviewer. Table 4 shows the results of the ANOVA. When looking at the difference between genders the p value was .075, which means that there was no significant difference between males and females on their scientific explanation scores. Based on the ANOVA, the difference between reviewers was not significant with a p value of .420. When looking at the interaction between gender and reviewer the p value was .499. Therefore, no significant difference existed in the achievement levels of the scientific explanations between male and female students based on whether they received peer feedback or teacher feedback.

Table 4

Results of Univariate Analysis of Variance

Source	F	Sig.
Gender	3.364	.075
Reviewer	.666	.420
Gender*Reviewer	.466	.499

a. R Squared = .126

Overall there were 25 females and 13 males for a total of 38 students and an even split of 19 students in each class. As Table 5 shows, both classes had a similar number of males, and both had a similar number of females. Each class

had more females than males. The average scores for the four different groups are listed in Table 5.

Table 5

Average scores and standard deviation on scientific explanations out of a possible 9 points of female and male students receiving teacher feedback and peer feedback.

	Females with teacher feedback	Females with peer feedback	Males with teacher feedback	Males with peer feedback
Number of students	12	13	7	6
Average Score out of a possible 9	8.25 out of 9	8.06 out o 9	7.79 out of 9	7.75 out of 9
Standard Deviation	3.3	3.0	3.3	4.3

Question Three

What was the difference in the scientific explanations over time between students who receive teacher feedback and students who receive peer feedback during the writing process?

The results of the repeated measures general linear model showed that there was a significant effect of time on the scores of the scientific explanations for both peer-reviewed and teacher-reviewed explanations. Assuming a Greenhouse-Geisser correction the p value was .005 for the difference in scores as a result of time (Table 6).

There was no significant difference over time between the peer-reviewed and teacher-reviewed groups' scores ($p=.88$). This seems to indicate that what

makes the biggest difference in the improvement of scientific explanations is practice in actually writing them and not whether a teacher or peer is reviewing the rough draft. There is a significant effect of practice, and students need to go through the process of writing scientific explanations again and again in order to get better at them.

Table 6

General Linear Model of Repeated Measures

Tests of Within-Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square
ExplanationTime Greenhouse-Geisser	10.862	2.567	4.231
ExplnationTime*Reviewer Greenhouse-Geisser	.388	2.567	.151
Error(ExplanationTime) Greenhouse-Geisser	78.000	92.418	.844

Source	F	Sig.
ExplanationTime Greenhouse-Geisser	5.013	.005
ExplanationTime*Reviewer Greenhouse-Geisser	.179	.884

The students in this study who received peer feedback had an average score of 7.84 on their first written explanation and by the fourth explanation they had increased the average score to 8.47 (Table 7). With each consecutive

explanation, the students giving peer feedback wrote more in-depth rough drafts and gave more concise feedback to each other. The reasoning section of the scientific explanation was difficult for the students even on the final explanation because they just did not have the depth of understanding required in the explanations. Most of the points were taken away on the rubric in the reasoning section.

Table 7

Average score on each explanation by review group out of a possible 9 points

	Explanation 1	Explanation 2	Explanation 3	Explanation 4
6 th Grade Average Score: Teacher Feedback	8.05	7.79	8.05	8.42
Standard Deviation	0.9	1.3	1.0	0.9
7 th Grade Average Score: Peer Feedback	7.84	7.63	7.89	8.47
Standard Deviation	1.3	1.4	1.2	0.8

Question Four

What was the difference between the gain of content knowledge based on the pretest and posttest scores when receiving peer feedback versus teacher feedback on scientific explanations?

Analysis of the pretest to posttest data by groups using the general linear model (Table 8) was not statistically significant ($p = .557$). Posttest scores were not affected by a student receiving peer reviews or teacher reviews on their scientific explanations.

Table 8

Tests of Within-Subjects Contrasts using a general linear model

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Gain Score from pretest to posttest Linear	726.645	1	726.645	114.919	.000
Gain*Reviewer Linear	2.224	1	2.224	.352	.557
Error(prepost) Linear	222.632	36	6.323		

Both classes started with very similar mean scores on the pretest with 10.74 (6th grade) and 10.94 (7th grade). Both classes also made gains in content knowledge throughout the unit.

Table 9

Average scores out of a possible 20 on pretest and posttest and average gain with standard deviation from pretest to posttest by review group

	Average pretest score	Average posttest score	Average gain from pretest to posttest	Standard Deviation
6 th Grade: Teacher Review	10.74	17.26	6.53	3.37
7 th Grade: Peer Review	10.94	16.79	5.84	3.73

Both classes showed significant gains in writing scientific explanations with the feedback from a peer or the teacher. It was not significant whom the student received feedback from, but the feedback was an important step in the writing process for all of the students. Because both groups of students made significant gains in writing scientific explanation over time, I wanted to look at both groups to determine what the correlation was between writing scientific explanations and learning the content knowledge of the unit. As Table 10 shows, the Pearson Correlation between the scientific explanation scores and the posttest ($R=.608$) was significant ($p=0.01$). Based on the significant gains in the scientific explanations over time for both groups a case can be made that writing scientific explanations and receiving feedback during the process is likely a causal mechanism for the gain in content knowledge.

There was also a significant correlation ($R=.342$) between the scientific explanation scores and the gain score from pretest to posttest, which was significant ($p=0.05$). This can be seen on Table 11. Writing scientific explanations accounted for 36% of the score (Figure 3) on the posttest and 11.7% of the gain score from pretest to posttest (Figure 4).

Table 10

Pearson Correlations between scientific explanation scores and posttest

		Total Explanation Score	Posttest Score
Total Explanation Score	Pearson Correlation	1	.608
	Sig. (2-tailed)		.000
	N	38	38
Posttest Score	Pearson Correlation	.608**	1
	Sig. (2-tailed)	.000	
	N	38	38

** Correlation is significant at the 0.01 level (2-tailed)

Figure 3

Percentage of posttest score that can be explained by the writing of the scientific explanations

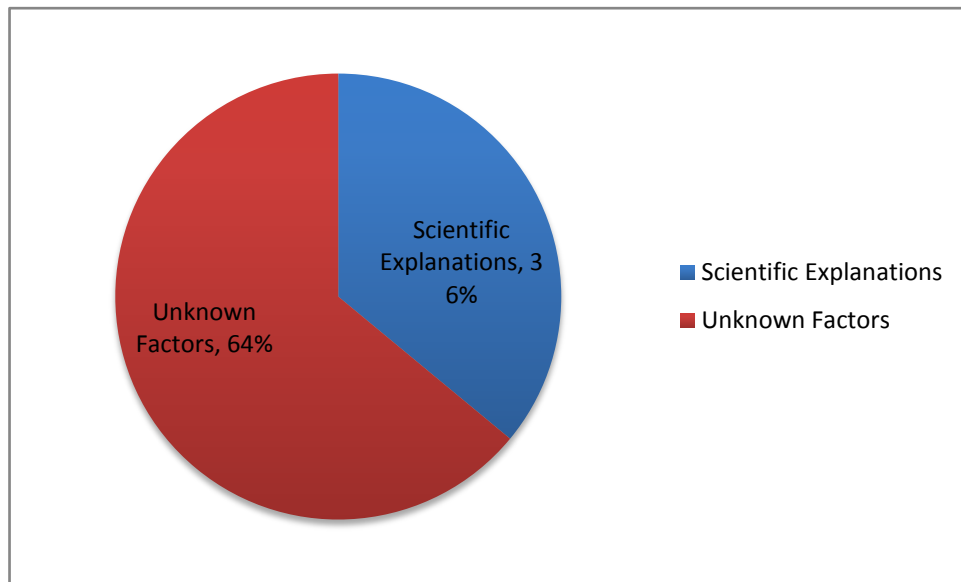


Table 11

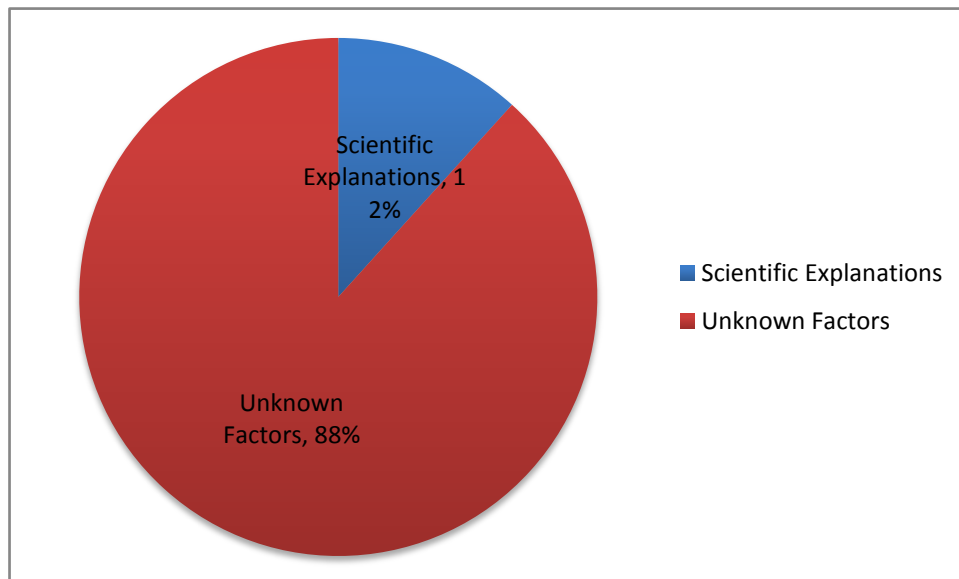
Pearson Correlations between scientific explanation scores and posttest

		Total Explanation Score	Gain Score
Total Explanation Score	Pearson Correlation	1	.342
	Sig. (2-tailed)		.036
	N	38	38
Gain Score	Pearson Correlation	.342*	1
	Sig. (2-tailed)	.036	
	N	38	38

*Correlation is significant at the 0.05 level (2-tailed)

Figure 4

Percentage of gain score that can be explained by the writing of the scientific explanations



Question Five

What did the students perceive about the quality of the feedback and the usefulness of giving and receiving feedback based on which group they were in?

The principal conducted a survey with all of the students from both classes to gain a deeper understanding of the results. He took the students in groups of three or four in order to expedite the process and promote discussion among the students. The questions were designed to gain an understanding of how the students felt about receiving the feedback, if they would have preferred receiving feedback in a different way, and if they used the feedback they received when making revisions. See appendix B for a complete listing of the questions.

The students who received feedback from the teacher unanimously said that they found the feedback helpful because it gave them specific ideas “of what needed to be added and also what to delete.” They felt that getting feedback on the rough draft helped them know what to improve upon. Most of the groups felt that there was a direct connection between using the feedback and “getting a better grade” because they knew how to “change [the explanation] and be more scientific.”

These students in the teacher feedback group also all felt that they would prefer not to receive feedback from a student instead of the teacher. They said that the teacher has more experience and knowledge about science, and “students don’t know everything yet.” At times because of this deeper knowledge, students did not always understand the feedback because “sometimes it was complicated and they had to ask what it meant.”

Not surprisingly, the students who received peer feedback had more mixed feelings about the process of receiving and then giving feedback. When asked if they found the feedback from peers to be helpful when revising half of the groups said yes it was very helpful and told “us what to do better” but they also said that sometimes the feedback was “not always trustworthy.” Other groups either said that it really “depended on the person giving the feedback.” They felt that some peers were helpful and some were “too vague” or things were corrected that needed no correction.

All of the groups did feel that they used the feedback from their peers to be more specific and add more details on the final explanations. However, they could not always use the feedback given because it was “bad advice.” Overall they felt they could use the feedback on the rough draft to “expand and improve” their work and get a better grade.

They were also asked about the process of giving feedback. One group had no response, but the other groups were positive about the experience of giving feedback. They felt that it was good to learn how to give honest detailed feedback. They also felt that it “helped with your explanation to know what not to do and what you might want to do” when you evaluated other students’ work.

Chapter 6

DISCUSSION AND IMPLICATIONS

Although there was no significant difference found between the groups receiving peer feedback and teacher feedback several things can be learned from this study. The writing process is a long and involved process in the classroom. It can be daunting for a teacher to read every rough draft and give meaningful feedback and then read every final draft as well. So, it is good to know that having the students give peer feedback will not harm the quality of the students' final draft. However, teachers need to be careful that they do not just tell the students to give feedback. A key component of the writing was practicing giving feedback each time before the students would actually give feedback to each other. The students also exchanged with two other students and this was time consuming.

Nicol and Macfarlane-Dick (2006) found that peer feedback gave students a great sense of control over their own learning allowing them to explain the concepts more easily and develop a detachment from their own work so they can assess it more easily. Kastrá et al. (2001) found that peer review was a powerful motivator to students and they had a more positive attitude toward writing. This study confirmed what was found in previous studies. The students who gave the peer feedback stated that the process of giving feedback was overall positive for their own writing. Giving feedback involved the students more deeply in the process of writing. Since writing is a complex process, the more that the students

can learn about the process the better. Being an integral part of the writing process is an invaluable experience for the students.

Teachers are still able to give more reliable feedback and are more able to identify mistakes and misconceptions (Nicol and Macfarlane-Dick, 2006). The performance of *all* students improved with written feedback from the teacher (Konold, et al., 2004). This study showed that the students who received teacher feedback clearly benefited from the feedback in their writing and learning of content knowledge. I therefore believe that a mixture of teacher feedback and peer feedback would be best. The students need to have access to teacher feedback in order to tap into that deeper understanding that the teacher is able to give, but not every student needs teacher feedback every time to produce excellent writing. When students are taught how to give feedback they can do just as well as the teacher and be more integrally involved in the writing process.

An area that the students continued to have difficulty with when giving feedback was on the reasoning section, which required a good understanding of the larger conceptual framework. This is a struggle even for teachers, but it is an important aspect of not just scientific explanations but of science class in general. If teachers make it a priority to discuss the big ideas of the discipline and teach to those big ideas, students will start to see the connections from the small pieces of evidence to the larger conceptual framework. The more practice they have looking for those connections the better they will become at it.

Having peers give each other feedback allowed them one more avenue to make the connections to that conceptual framework. It also allowed students to

participate in science as a socially-driven discipline. They were able to experience the authentic way that science is developed. According to Brown et al. (1989) students need to use the tools of science and it is only through that use that they will learn the culture of the discipline.

In this study the students giving and receiving feedback from a peer or the teacher were more engaged in the true culture of science. They were faced with having to decide if the feedback was useful. Those giving feedback decided if the other student addressed the big idea in their reasoning or not. During the time that students are giving feedback, the teacher could be moving around the room to make sure that the peer evaluators are looking for that big idea in the reasoning. This could be another way that peer and teacher evaluations could work in conjunction.

Past research has shown the strong connection between writing and learning. Akkus et al. (2007) found that an emphasis on collaboration on scientific explanations, which would include feedback, significantly increased content knowledge. McNeill et al. (2006) also found a significant correlation between content knowledge and scientific explanation scores. This study was no different. This study showed that there was a significant correlation between the writing of the scientific explanations and the score on the posttest and the average gain score. 36% of the posttest score was accounted for by the scientific explanation score and 12% of the average gain score is directly related to the writing of scientific explanations. This is a large amount of the posttest score and gain score that is directly related to the writing of scientific explanations. With

the significant increase in the scores of the scientific explanations over time, it can be inferred that there is a causal relationship between the writing of scientific explanations and the posttest score and gain score.

Students had extended time with the material that they were learning in the earth systems unit because they had to write a rough draft, edit and rewrite it. Each time they looked at their scientific explanations, they were also looking at the content knowledge. This gave them more exposure to the scientific facts and to the larger conceptual framework than if they had just read a section in the textbook and answered questions based on the reading. They had to discover the content through inquiry activities first and then write about it at least twice; therefore, it was not surprising to see such a strong correlation.

For both groups, the goal of scientific literacy put forth by the *National Science Education Standards* (NRC, 1996) and the *American Advancement for the Achievement of Science* (AAAS, 1993) were worked toward in the classroom in a real way. The students made informed decisions on issues. They developed the skills required for creating scientific explanations including the ability to articulate a theory, and to understand the type of evidence that could support or contradict that theory (Zimmerman, 2000).

Future Research

No significant difference was found between groups that received feedback, but there was a significant effect of practice on the improvement of the scientific explanations. Giving feedback is a time-intensive process that a majority of teachers unfortunately do not do on each writing project due to time

constraints. Self-evaluation and feedback therefore is an important skill for students to learn in order to edit and produce excellent final drafts without the help of a teacher or peers on every writing assignment. A study should be conducted to see if there is the same outcome with a group that is taught to evaluate their own rough drafts. Would time and practice still have the same effect of improving their writing? Is it purely the process of revising and rewriting that matters over time, or do middle school writers need others to look at their work?

Unfortunately, middle school students do not often go back and rewrite a rough draft even when they do receive feedback. So it would also be interesting to see if the same improvements in writing scientific explanations would be there without revisions. And if students do not go through the whole writing process every time, would the correlation between the writing of the scientific explanations and the gain scores from pretest to posttest remain the same? I believe that the revision stage is not only important for producing a better final scientific explanation, but it is also a time for the students to review the content material and consolidate it in their brains thereby making the gain in content knowledge greater and deeper.

Limitations

There were a number of limitations in this study. The classes were chosen because they were the only two classes that were receiving the same content of earth science. However, having one 6th grade and one 7th grade class was not ideal and perhaps contributed to the difference in the outcome. Differences in

achievement levels among the students could have caused differences in data collection. The 7th grade has at least one more year of exposure to science content and practice in writing. The outcome may have been completely different if the treatment had been applied in the opposite way with the 7th graders receiving teacher feedback and the 6th graders receiving peer feedback.

Another limitation in this study was that although both classes only have the teacher for one period of science during the day, the teacher is the homeroom teacher for the 7th graders, which means that they have upwards of 2.5 more hours of instruction time in other subjects with that teacher. One of the other subjects is writing, and this means that the 7th graders may already have a better idea of what the teacher was looking for in their writing. This could also have caused a motivational difference if certain students either were more or less willing to work hard for the teacher based on a longer relationship with the teacher.

The unit of instruction proved to be longer than was originally expected due to interruptions in the school year with bad weather causing sporting events to be rescheduled changing the amount of instruction time which pushed the unit past spring break. The school also had a week of unexpected time off due to a water leak and damage. So the entire unit ended up lasting 8 school and 11 calendar weeks as opposed to the 7 weeks that were originally planned. The number of days of instruction were as planned, but the length of the entire unit from day one to the end was much longer than expected. Therefore, students may have forgotten much more content knowledge than if the unit had ended when expected. This could have changed the results of the posttest.

Other limitations of this study were the assessment tools. The base explanation rubric was an excellent starting point for writing and grading scientific explanations for a general science class. It had a total possible score range of 3 to 9 points with 3 points possible for each section of the explanation: the claim, the evidence, and the reasoning. The tool had a ceiling effect from the start. There were students who received scores of 9 on all four explanations but truly did make improvements on their writing over the course of the unit. I believe that the scoring was as fair as it could be and that they did deserve a 9 on all of the explanations according to this rubric but a more sensitive rubric would have shown those improvements. A tool with more distinct and detailed differences on the various levels would have given a more accurate picture of the true difference between each student's explanations. The grading categories of claim, evidence, and reasoning did not have fine enough distinctions to separate the writing enough which meant that a very well written explanation and a decent explanation might have received the same grade even though one was clearly superior. In future studies, I would perhaps start with the base explanation rubric and turn it into a 4 or 5-level rubric as opposed to a 3-level rubric. I would also consider adding either more categories to the evidence and reasoning sections or adding more weight to those sections since they required far more writing to make them worthy of a top-level score.

As with any rubric, there is still possibility of subjective grading. While the researcher did attempt to establish a small degree of reliability by having several other teachers score five of the different scientific explanations throughout

the unit and establish agreement, it was not truly reliable because those other teachers did not have the same comfort level with the content of the unit and the rubric. It would have been better if there were two people grading a number the same explanations to determine inter-rater reliability before grading the rest of the explanations separately. This was not a possibility in this study though. So there may be a certain level of subjectivity in the grades on the scientific explanation scores, which could have affected the final data.

The other assessment tool was the pretest/posttest. I believe with some editing and trials with actual students, that it could become a good assessment tool. The format of two-tiered multiple choice has some excellent advantages over a traditional multiple-choice test because students must show they understand the reasoning behind the factual knowledge. However, the test was written by the teacher specifically for this unit in order to assess the content knowledge of the unit. There was no opportunity to pilot the test before this study. Therefore, the reliability was determined after the study was over and had a Cronbach's alpha score of .629, which is not considered to be high reliability. Therefore, because it only had small reliability, this was a major limitation of the study and most likely had an affect on the data analysis.

While the survey found some of the students' thoughts on the unit and the feedback, it had several limitations. The principal conducted it in order to allow the students to talk more openly about teacher of the unit. However, some of the students may not have been comfortable discussing the questions with the principal. The principal also did not have a deep understanding of the unit and

therefore may not have prompted for a deeper response or clarification. The survey was also conducted in small groups, and only certain students talked during the discussion. A one-on-one survey would have been able to get all of the students' thoughts as opposed to the more verbal and outgoing students. Time constraints did not allow for this.

REFERENCES

- American Association for the Advancement of Science (AAAS). 1994. *Project 2061: Benchmarks for science literacy*. New York: Oxford University Press.
- Akkus, R. Gunel, M Hand, B. (2007). Comparing an inquiry-based approach known as the science writing heuristic to traditional science teaching practices: are there differences? *International Journal of Science Education*, 29(14), 1745-1765.
- Armstrong, N. Wallace, C. Chang, S. (2007). Learning from writing in college biology. *Res Sci Educ*, 38, 483-499.
- Brown, J. S, Collins, A., Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., Landes, N. (2006). The BSCS 5E instructional model: origins, effectiveness, and applications. Executive Summary.
- Cavagnetto, A. R. (2010). Argument to foster scientific literacy: a review of argument interventions in K-12 science contexts. *Review of Educational Research*, 80, 336-371.
- Chin, C. Brown, D. (1999). Learning in science: a comparison of deep and surface approaches. *Journal of Research in Science Teaching*, 37 (2), 109-138.
- Hand, B. Prain, V. (2002). Teachers implementing writing-to-learn strategies in junior secondary science: a case study. *Science Education*, 86(6), 737-755.
- Jensen, W., Fischer, B. (2005). Teaching technical writing through student peer-evaluation. *Journal of Technical Writing and Communication*, 35(1), 95-100.
- Katstra, J., Tollefson, N., Gilbert, E. (2001). The effects of peer evaluation on attitude toward writing and writing fluency of ninth grade students. *Journal of Education Research*, 80(3), 168-172.
- Kendall, J. S., & Marzano, R. J. (2004). *Content knowledge: A compendium of standards and benchmarks for K-12 education*. Aurora, CO: Mid-continent Research for Education and Learning. Online database: <http://www.mcrel.org/standards-benchmarks/>
- Keys, C. W. (1999). Language as an indicator of meaning generation: An analysis of middle school students' written discourse. *Journal of Research in Science Teaching*, 36, 1044-1091.
- Keys, C. W., Hand, B., Prain, V. & Collins, S. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching*, 36, 1055-1084.
- Konold, K. E., Miller, S. P., Konold, K. B. (2004). Using teacher feedback to enhance student learning. *Teaching Exceptional Children*, 36(6), 64-69.
- Jiminez-Aleixandre, M. P., Rodriguez, A. B., Duschl, R. A. (1999). "Doing the lesson" or "doing science": argument in high school genetics. *Science Education*. 84(6), 757-792.

- McNeill, K. L. & Krajcik, J. (2008). Inquiry and scientific explanations: Helping students use evidence and reasoning. In J. Luft, R. L. Bell and J. Gess-Newsome (Eds.), *Science as inquiry in the secondary setting* (pp. 121-134), Arlington, VA: NSTA Press.
- McNeill, K. L., Lizotte, D. J., Krajcik, J., Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences*, 15(2), 153-191.
- National Research Council (2006). *America's lab report: investigations in high school science*. Washington D.C.: National Academy Press.
- National Research Council. (1996). *National science education standards*. Washington DC: National Academy Press.
- Nelson, M. M., Schunn, C. D., (2007). The nature of feedback: how different types of peer feedback affect writing performance. *Instructional Science*, 37, 375-401.
- Newton, P., Driver, R., Osborne, J. (1999). The place of argumentation in the pedagogy of school science. *International Journal of Science Education*, 21(5), 553-576.
- Nicol, D. J., Macfarlane-Dick D. (2006). Formative assessment and self-regulated learning: a model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199-218.
- Novak, A. M., McNeill, K. L., Krajcik, J. S. (2009). Helping students write scientific explanations. *Science Scope*, 33(1), 54-56.
- Osborne, J. F. (2009, 2010). An argument for arguments in science classes. *Kappan*, 91(4), 62-65.
- Osborne, J., Erduran, S., Simon, S (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020.
- Osborne, J., Erduran, S., Simon, S (2004b). *Ideas, Evidence and Argument in Science (IDEAS) Project*, London, UK: King's College London.
- Prothero, W. A., Kelly G. (2006). Earth data, science writing, and peer review in a large general education oceanography class. *Journal of Geoscience Education*, 56(1), 61-72.
- Rivard, L. P. (2004). Are language-based activities in science effective for all students, including low achievers? *Science Education*, 88, 420-442.
- Sampson, V., & Clark, D. (2008). The impact of collaboration on outcomes of scientific argumentation. *Science Education*, 93(3), 448-484.
- Toulmin, S. (1958). *The uses of argument*. Cambridge, UK: Cambridge University Press.
- Venables, A., Summit, R. (2003). Enhancing scientific essay writing using peer assessment. *Innovations in Education and Teaching International*, 40(3), 281-290.
- Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

- Wallace, C. S. (2004). An illumination of the roles of hands-on activities, discussion, text reading, and writing in constructing biology knowledge in seventh grade. *School Science and Mathematics*, 104(2), 1-9.
- Wallace, C. (2004). Framing new research in science literacy and language use: authenticity, multiple discourses, and the “third space”. *Science Education*, 88, 901-914.
- Yore, L. Hand, B. Goldman, S. Heldebrand, G. Osborne, J. Treagust, D. Wallace, C. (2004). New directions in language and science education research. *Reading Research Quarterly*, 39(3), 347-352.
- Zemal-Saul, C. (2008). Learning to teach elementary school science as argument. *Science Education*, 93(4), 687-719.
- Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review*, 20, 99-149.
- Zohar, A., Nemet F. (2001). Fostering students’ knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*. 39, 35-62.

APPENDIX A
BASE EXPLANATION RUBRIC

Base Explanation Rubric

Component	Level		
	1	2	3
<i>Claim-</i> A conclusion that answers the original question.	Does not make a claim, or makes an inaccurate claim.	Makes an accurate but incomplete claim.	Makes an accurate and complete claim.
<i>Evidence-</i> Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim.
<i>Reasoning-</i> A justification that links the claim and evidence. It shows why the data count as evidence by using appropriate and sufficient scientific principles.	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.	Provides reasoning that links the claim and evidence. Repeats the evidence and/ or includes some— but not sufficient— scientific principles.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

APPENDIX B
SURVEYS QUESTIONS

Survey Questions to ask Class A

1. Did you find receiving teacher feedback helpful when you were revising your scientific explanations? Why?
2. How did you use the feedback when you rewrote your explanation?
3. Can you give a specific example?
4. Would you have preferred to receive feedback from a student instead? Why or why not?
5. What is one thing that the teacher could do to give you better, more useful feedback?
6. Did you understand the feedback that the teacher gave you? If not, what didn't you understand?
7. Did you use the feedback that I gave you in rewriting your explanations? If not, why not?
8. Do you think that getting feedback on your rough drafts helps you write a better final draft? Why or why not?

Survey Questions to ask Class B

9. Did you find the feedback from your peers to be helpful when you were revising your scientific explanations?
10. Did you learn anything when you gave feedback to your classmates? If so what did you learn?
11. Would you have preferred to receive feedback from the teacher instead? Why or why not?
12. How did you use the feedback when you rewrote your explanation?
13. Can you give a specific example?
14. Did you understand the feedback that your peers gave you? If not, what didn't you understand?
15. Did you use the feedback that your peers gave you in rewriting your explanations? If not, why not?
16. Do you think that getting feedback on your rough drafts helps you write a better final draft? Why or why not?

APPENDIX C
UNIT OF INSTRUCTION

Unit: Earth System

Earth Science: Grade 6,7

Designer: Katie Lange

Big Idea: Earth is a complex system of interacting rock, water, air and life.

Established Goals (NSES):

Structure of the Earth System:

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
- The atmosphere is a mixture of nitrogen, oxygen and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- Clouds, formed by the condensation of water vapor, affect weather and climate.

Understandings (Emmanuel Lutheran School Standards):

- Knows the composition and structure of Earth's atmosphere.
- Knows the processes involved in the water cycle.
- Knows that the Sun is the principle energy source for phenomena on Earth's surface.

Learning Plan

Lesson One: The structure of scientific explanations (2-3 days)

Lesson Overview: In this lesson, students will learn the key elements of a scientific explanation and critique of scientific explanations using the rubric.

Understandings:

- Understands the nature of scientific explanations.
- Establishes relationships based on evidence and logical argument.

Pretest: Give the students the multiple choice unit pretest.

Review: What makes a good scientific explanation? (Look back in your notebooks)

Learning Plan: Have students look at several examples of explanations (From IDEAS pack) and in groups have them look for the key pieces of the explanation. When students bring up different pieces such as ‘evidence’ ask ‘why do you need evidence?’ or ‘reasoning’ ask ‘what is reasoning and why do you need it?’ “Can evidence just stand alone?” “What happens when someone disagrees with you?” Guide students to see that a good scientific argument or explanations includes claim, evidence and reasoning.

Students will then create posters that have the three key elements of an explanation: claim, evidence and reasoning and put into their own words what each element means. The posters will then go up around the room.

Practice and Review: Give students the generic rubric for creating scientific explanations to put in their science notebooks, and tell them that they will have practice creating and critiquing scientific explanations in the upcoming lessons. Project the following examples (From Science as inquiry in the secondary setting, by Luft, Bell, and Gess-Newsome, and Helping students write scientific explanations by Novak, McNeill, and Krajcik) from science and the everyday world for students to find the claim, evidence and reasoning and to critique each using the rubric:

- Yes. See my data table on fat and soap. The reason they are different is that they have different properties.
- Fat and soap are different substances. Fat is off-white and ivory and is milky white. Fat is soft and squishy and soap is hard. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. The melting point for the fat was 47°C , while soap was over 100°C . The density of fat is 0.92 cm^3 , and the density of soap is 0.84 cm^3 . These are all properties. Because fat and soap have different properties, I know they are different substances. Different substances always have different properties.

Lesson Two: Introduction of Earth Systems: Geosphere and Hydrosphere (5 -6 days)

Lesson Overview: In this lesson, students will revisit Earth's interior to establish this as the first part of the complex system that makes Earth what it is, and then they will create the water cycle to introduce the hydrosphere.

Understandings:

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.

Materials:

- Whiteboards/markers
- Models of Earth's interior
- Water cycle die

Review: Students will do a quick write telling me everything they know about systems. From this we will come up with a definition of a system in science. Students will have already learned about the rock cycle and Earth's interior during the plate tectonics unit. They will know the layers of the Earth and how scientists know about the different layers. I will ask students to go back to their notes on Earth's interior and review the various layers. I will also pull out a model and review with the students. I will ask the students how this fits as an example of an Earth system.

Engage: Give students the hydrosphere POE. Go over the Predict section and have students write their initial thoughts.

Explore: The purpose will be to explain another Earth system, the hydrosphere: Does water disappear from Earth? What do we need to do in order to explain where the water goes? I have an activity set up for you that simulates what happens to water when it rains and what happens after it rains.

As individual students will be participating in the journey through the water cycle game. There will be 5-7 stations set up around the room of where the water cycle occurs. Students will go to each station and roll the water cycle dice to determine what path they should take. They will write down what state of water they are at each station and then what process occurs to make them go to the next station. After they game is over they will have recorded what has happened through their journey.

Explain: Back at learning communities students will divide whiteboard into sections and make bullet points of their journey. As a class they then will create a

class list of different possibilities of the relationships they observed during the activity.

Expand: Each group will create a pictorial model of the relationships of the different states of water and how they moved from one state to the next. The class will create a consensus of a picture of the water cycle to put in the observation sections of their POE form.

Elaborate: Create a mini-water cycle. What stations were involved in the water cycle? How could we bring this down to a small scale?

Through the following questions during whiteboard presentations, I want students to explore the idea of the water cycle and the fact that water cannot disappear but it can move through many different phases..

- How can water from (name a stage) become water from a (different stage)?
- Do you think that water last forever? How do you know?
- How does the water cycle show the Earth is continuously changing?
- What does the water cycle show you about Earth?
- What would happen to the Earth if the water cycle stopped?
- Why is the water cycle happening?
- How do we know the water cycle is happening?
- What do you think causes the water cycle?
- How can you use the water cycle as evidence that the Earth is continuously changing?
- What is another example of the Earth continuously changing? Can you think of another cycle?
- How do the water cycle and Earth's interior interact?
- We called Earth's interior the geosphere. What do you think geo means? What does sphere mean?
- Can you think of a Greek word for water?
- So what might we call the all of the water contained on Earth?
- How do the geosphere and hydrosphere interact?
- How do the biosphere and hydrosphere interact?
- What is a system?
- What are some examples of systems that we have talked about?
- How is the water cycle an example of an Earth system?

Evaluate: Write a scientific explanation answering the question Does water disappear after it rains? Remind the students of the format for a scientific explanation reviewing the good explanation, the rubric

*For this explanation, the big idea that the students will see emphasized is the concept of the water cycle as a closed system, therefore the water cannot disappear. It will just continue in a cycle moving from one part of the system to another.

For class A, have the students turn in the rough draft and the teacher will highlight the claim, evidence and reasoning and use the rubric and the argument prompts to give specific advise. After the teacher evaluation, the students will have to revise and turn in a final copy.

For class B, the students will have a lesson on peer evaluating (see below). Then the students will do a peer evaluation for each other's explanations. After the peer evaluations, the students will revise them and then turn in a final copy.

Peer Evaluating Lesson: Being the Teacher

Lesson Overview: In this lesson the students will practice giving feedback on scientific explanations using the rubrics and argument prompts.

Understandings: Evaluates the results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists.

Peer evaluating is when students help evaluate each other's scientific explanations. You have already had some practice in this when you were critiquing the scientific explanations as a class last week. The steps for peer evaluation include highlighting the claim in one color, the evidence in another color and the reasoning in a third color. Then you will use the rubric and argument prompts to decide what specific things they are doing well and which things they need to improve. You will then need to make comments on their explanation that will allow them to improve their scientific explanations. Let's practice on the following explanation in groups

- Does water disappear after it rains? Claim: No. Evidence: See my data table that I always moved from station to station. Reasoning: The water cycle is a cycle which means it won't disappear.

Now practice giving feedback on this argument by yourself.

- The water has not disappeared. The water soaked into the ground after it rained. We did a simulation in class and you can see my data. I know this simulation is right because this is one of the steps in the water cycle.

Lesson Three: Should we restore the wetlands? (4-5 days)

Lesson Overview: This activity is an opportunity for students to explain a socio-scientific issue. This issue is described to students in a letter and they are asked to argue for or against the issue—in this case, the need for the restoration of a wetland area—and provide justifications for their point of view.

Understandings:

- Water, which covers the majority of the earth’s surface, circulates through the crust, oceans, and atmosphere in what is known as the “water cycle.” Water evaporates from the earth’s surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.

Materials: Letter, Newspaper, loaf pan, damp soil, water, beaker, sponge

Learning Plan:

Distribute the letter to the students and read together. Emphasize the purpose of the activity- to create a scientific explanation which includes evidence and reasoning to support a decision for or against restoring the wetland area.

Allow the groups to brainstorm everything they know about wetland areas on whiteboards and compare similarities and differences. Based on the prior knowledge, come up with specific questions to research on wetlands.

Have students discuss what a wetland is composed of to see if we can set up a mini-wetland to observe to help in our decision-making. Use page 401 in the science text as a starting point.

Have a group discussion to stimulate thinking on both sides of the argument.

1. How do wetlands help with pollution?
2. Could we clean the polluted water in a water treatment plant instead?
3. Where do we find wetlands in the United States?
4. What types of wildlife live in wetlands?
5. Could those plants and animals live somewhere else?
6. How do wetlands control floods?
7. Could we design canals to control flooding instead?
8. How is the hydrosphere interacting with the geosphere?
9. Do plants also play a role? We call this the biosphere.
10. How do all three systems interact?

Assessment: Write a scientific explanation to support your decision to restore or not restore the wetland. Include your claim, evidence to support your claim and reasoning to tie your argument together.

*The big idea that students will see emphasized in this lesson is that all of the systems: hydrosphere, geosphere and biosphere, work together to support life on earth. The geosphere and plants in the biosphere help to filter the pollutants out

of the hydrosphere. The geosphere can absorb a great deal of water to keep the land from flooding.

For class A, have the students turn in the rough draft and the teacher will highlight the claim, evidence and reasoning and use the rubric and the argument prompts to give specific advise. After the teacher evaluation, the students will have to revise and turn in a final copy.

For class B, the students will do a peer evaluation for each other's explanations. After the peer evaluations, the students will revise them and then turn in a final copy.

Peer Evaluating Lesson: Being the Teacher

Lesson Overview: In this lesson the students will practice giving feedback on scientific explanations using the rubrics and argument prompts.

Understandings: Evaluates the results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists.

Peer evaluating is when students help evaluate each other's scientific explanations. You have already had some practice in this when you were critiquing the scientific explanations as a class last week. The steps for peer evaluation include highlighting the claim in one color, the evidence in another color and the reasoning in a third color. Then you will use the rubric and argument prompts to decide what specific things they are doing well and which things they need to improve. You will then need to make comments on their explanation that will allow them to improve their scientific explanations. Let's practice on the following explanation in groups

- Claim: Yes, restore the wetlands. Evidence: My experiment shows that they are a filter. Reasoning: All of the spheres work together so we need the wetland as part of that process.

Now try one on your own.

* Claim: Yes we need to restore the wetlands to allow the biosphere, geosphere and hydrosphere to work together. Evidence: The wetlands act as a filter. They make the water clean. Reasoning: All of the earth systems work together so we need the wetlands.

Lesson Four: The Atmosphere (5-6 days)

Lesson Overview: In this lesson students will discover the fourth interacting part of our Earth system: the atmosphere. They will find the components that make up the atmosphere and discuss why those components are important to support life on earth.

Understandings:

- Knows the composition and structure of Earth's atmosphere.

Materials: Tall glass jar, large cake pan, steel wool, water, tape, limewater, straw, beakers, goggles, whiteboards, markers, triple beam balance, balloons

Engage: We've talked about the geosphere (rock cycle) and the hydrosphere (water cycle) and the biosphere (living things) as examples of interacting systems on earth. Can you think of another system that sounds like geosphere, biosphere and hydrosphere? (Atmosphere) What is the atmosphere? What is it made of? Is air matter? Does matter have mass? Does air have mass? Use a balance and balloon to have the students measure the mass of air. What other properties of matter does the air have? Type one writing: Tell me everything you know about the atmosphere. Whiteboard results coming up with a working definition and especially looking at the ideas to do with the composition of the atmosphere and the atmosphere supporting life.

Explore: The question that we want to explore then is "What makes up the atmosphere and how does that help living things stay alive?"

Ask students what gas will make steel rust. Where does this gas come from? Is all of the air around us oxygen? Let's design an experiment to find out how much oxygen is in the atmosphere.

*Probable procedure: Have students fill a cake pan almost full of water. Then have them push the steel wool down into the bottom of the jar so it will not fall out when the jar is turned over. Have students fill the jar with water, cover the mouth with one hand, and place the jar upside down in the cake pan. Then students should remove the hand and tilt the jar slightly to let out enough water to make the water level in the jar just above the water level in the pan. Have students mark the water level in the jar with tape. Students should check the water level in the jar with tape. Students should check the water level in the jar the next day. It should be about one fifth higher.

Explain: Record the results on a class data table. What gas did we say was reacting with the steel? How much of the air in the jar was used up? What can we infer about the amount of oxygen in the atmosphere? Are there other factors that you would like to control to double check these results? Allow them to set up a new experiment possibly changing the amount of time that the steel wool is left in the system.

Expand: So if oxygen takes up about 20% of the atmosphere what other gases are in the atmosphere? Think about the water cycle. Where are any parts of the water cycle that were located in the atmosphere? Get out a cold glass of water and observe the condensation. Where are these drops of water coming from? Lead them to the idea of water vapor in the air. What do animals need to breathe in order to live? What do animals breathe out? We have a way of detecting carbon dioxide. Just like steel reacts with oxygen to create rust, limewater will react with carbon dioxide to create limestone.

Let's design an experiment to make sure that carbon dioxide is in the air.

*Probable procedure: Fill a beaker halfway with limewater. Using a straw, breathe slowly through the limewater for about a minute. Allow the water to sit overnight. The limestone should settle to the bottom.

Have the students use the internet and textbook to research the other components of the atmosphere and the use of each component.

This is another Earth system. What are the parts of this earth system? What are the other earth systems that we have learned about? How do the four systems interact with each other? How do they affect each other? Can we get rid of one earth system and still have life on earth?

Evaluate: Students will now have a large amount of evidence of the various gases in the atmosphere and how many of the gases support life on earth. At this time they will be asked to write a scientific explanation on the original question "What makes up the atmosphere and how does that help living things stay alive?"

* The big idea of this lesson is that the atmosphere is yet another system on earth that works to stay in balance to support life on earth.

For class A, have the students turn in the rough draft and the teacher will highlight the claim, evidence and reasoning and use the rubric and the argument prompts to give specific advice. After the teacher evaluation, the students will have to revise and turn in a final copy.

For class B, the students will do a peer evaluation for each other's explanations. After the peer evaluations, the students will revise them and then turn in a final copy.

Peer Evaluating Lesson: Being the Teacher

Lesson Overview: In this lesson the students will practice giving feedback on scientific explanations using the rubrics and argument prompts.

Understandings: Evaluates the results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists.

Peer evaluating is when students help evaluate each other's scientific explanations. You have already had some practice in this when you were critiquing the scientific explanations as a class last week. The steps for peer evaluation include highlighting the claim in one color, the evidence in another color and the reasoning in a third color. Then you will use the rubric and

argument prompts to decide what specific things they are doing well and which things they need to improve. You will then need to make comments on their explanation that will allow them to improve their scientific explanations. Let's practice on the following explanation in groups

- Claim: The atmosphere has oxygen and water vapor. Evidence: We did some experiments that showed oxygen and water in the air, and humans need oxygen to breathe. Reasoning: The atmosphere is a system on earth that keeps humans alive.

Now practice this one on your own.

- Claim: The atmosphere has many gases in it. Evidence: We did experiments and research that show what is in the atmosphere so see my data table and notes. Reasoning: We need these gases to live.

Lesson Five: Layers of the atmosphere (2-3 days) ***Non-explanation lesson

Lesson Overview: In this lesson students will learn the distinction and importance of the four layers of the atmosphere. They will be able to explain why the atmosphere is important to life on Earth.

Understandings:

- Knows the composition and structure of Earth's atmosphere.
- Knows that the sun is the principle energy source for phenomena on Earth's surface.

Materials:

Data tables with atmospheric temperatures, whiteboards, markers

Engage: Remember last lesson we showed that air has mass and other properties of matter. We also discovered the composition of the atmosphere and saw that it is a fourth earth system. Today we want to explore more about this earth system and how it affects life at different areas on earth. What is the atmosphere made of? Those are all made of elements found on the periodic table which is a table of the matter. Also remember that when something is made of matter we can draw particle pictures of it. Draw a particle picture of the atmosphere around you at the beach in San Diego and a particle picture if you went to the top of Mount Everest. Label each with the temperature of the atmosphere. Whiteboard and explain why the pictures are different.

Explore: Give students a data table containing the temperature of the atmosphere at different altitudes. Ask them to graph the data with a line graph comparing temperature and altitude.

Explain: The atmosphere is divided into four layers based on temperature. Discuss in your groups where you think the dividing lines would be and why. Whiteboard the graph with divisions and present.

Expand: Assign groups a different layer of the atmosphere. Give them a graphic organizer to fill in. Based on this create a poster for a gallery walk. Students will then record the data from the gallery walk into their science notebooks. As a class discuss the similarities and differences in each layer. For each layer discuss how it benefits life on earth. Does the system of the atmosphere stay the same all over the earth? As you can see the system changes depending on where we are on earth. What do these changes mean for humans? Can we live at the top of Mount Everest? Why or why not? Is the hydrosphere also different at that height? How? These systems are all interacting to support life on earth, and not every place is ideal.

Evaluate: Present in class with your group: "Are San Diego and Mount Everest both good places to live? Why or why not?"

Lesson Six: The Sun and it's Power

Lesson Overview: In this lesson students will investigate the various ways that the sun is the main source of energy powering these Earth systems.

Understandings

- * Knows that the sun is the principle energy source for phenomena on Earth's surface.

Engage: I will have students brainstorm all of the possible ways that the sun affects the various systems on earth: biosphere, hydrosphere, geosphere and atmosphere. They will come up with as many examples as they can. Pose the question for them to explain: What is the role of the sun in powering the earth systems?

Explore: Students will take the ideas that they came up with in the brainstorming session and design experiments to observe the sun's power in action. Possible experiments could include solar cells on calculators just to show the sun's power, putting plants in various locations or cover them to show that the sun is the source of the energy, setting up evaporation stations in different locations to see it powering the water cycle...

Explain and Elaborate: After the students conduct their experiments they will have to conduct research to explain their findings and present to the class what they discovered. The class will take notes to collect more evidence for their final explanation.

Evaluate: Students will write a scientific explanation answering the question What is the role of the sun in powering the earth systems?

*The big idea of this lesson is that the Sun is the principle energy source for phenomena on Earth's surface and the earth would not maintain any life without the Sun's energy.

For class A, have the students turn in the rough draft and the teacher will highlight the claim, evidence and reasoning and use the rubric and the argument prompts to give specific advise. After the teacher evaluation, the students will have to revise and turn in a final copy.

For class B, the students will do a peer evaluation for each other's explanations. After the peer evaluations, the students will revise them and then turn in a final copy.

Peer evaluating is when students help evaluate each other's scientific explanations. You have already had some practice in this when you were critiquing the scientific explanations as a class last week. The steps for peer evaluation include highlighting the claim in one color, the evidence in another color and the reasoning in a third color. Then you will use the rubric and argument prompts to decide what specific things they are doing well and which

things they need to improve. You will then need to make comments on their explanation that will allow them to improve their scientific explanations. Let's practice on the following explanation in groups

Claim: The sun powers the hydrosphere. Evidence: We saw how the sun caused evaporation. Reasoning: The sun is the main energy source on earth.

Now try one on your own:

Claim: The sun is the energy for the earth systems. Evidence: We did some experiments that showed the sun caused the changes in the systems for puddles and plants. Reasoning: If the sun went away life on earth would not survive since it is the main source of energy.

APPENDIX D
PRETEST/POSTEST

Student Code:

Earth Systems Pretest/Posttest

Multiple Choice

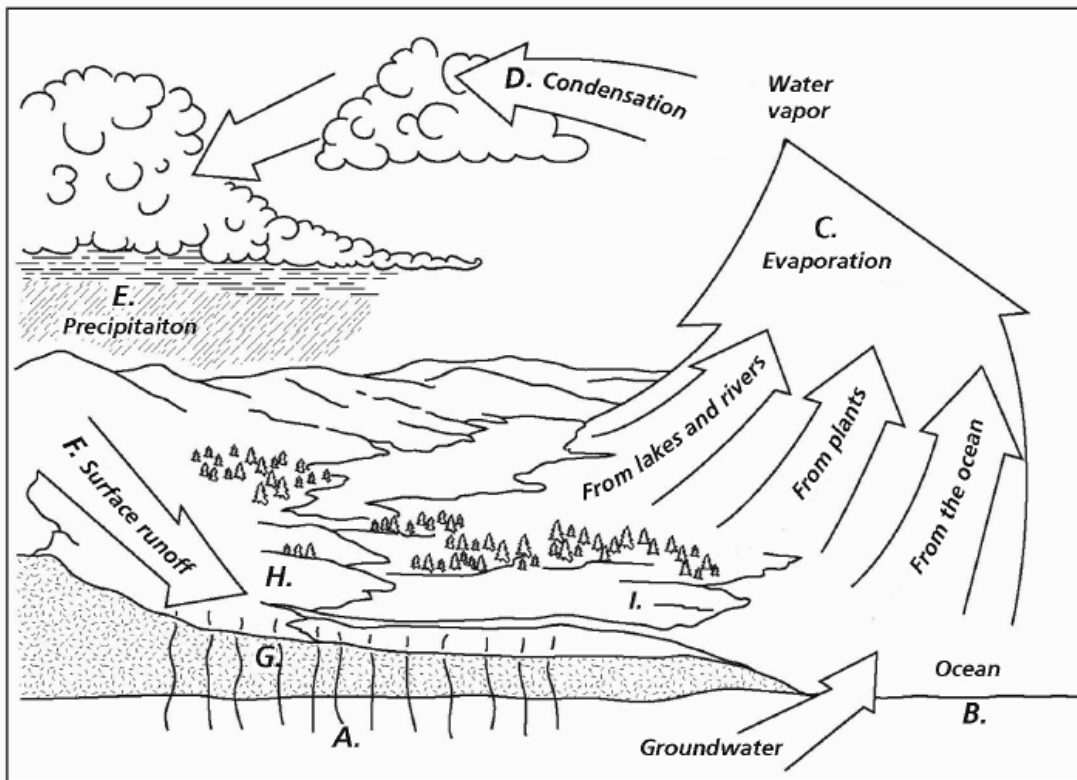
Identify the choice that best completes the statement or answers the question.

- ___ 1. The total amount of water on Earth
- a. is increasing.
 - b. is fairly constant.
 - c. is decreasing.
 - d. depends on the weather.
- ___ 2. How do you know how much water there is?
- a. The amount of water is decreasing because water is escaping to the sun.
 - b. The amount of water is increasing because it is always raining somewhere and the ice caps are melting.
 - c. The amount of water depends on the weather because rain can add more, but a drought makes it disappear.
 - d. The amount of water is fairly constant because the water moves from one location to another in a cycle.
- ___ 3. When walking on a high mountain,
- a. you can get out of breathe easily.
 - b. you breathe more oxygen.
 - c. you are hotter.
 - d. you breathe more carbon dioxide.
- ___ 4. This happens on the mountain because
- a. you are closer to the sun.
 - b. the air pressure is greater.
 - c. the percentage of oxygen increases.
 - d. there is less oxygen in each cubic meter of air.
- ___ 5. One of the main gases in the atmosphere is
- a. carbon dioxide.
 - b. water vapor.
 - c. oxygen.
 - d. argon.

- ___ 6. I know this because
- plants need the carbon dioxide to breathe.
 - when there is 90% humidity, that means the air is 90% water vapor.
 - when we burn a candle in a closed jar, the oxygen is used up leaving 20% less air.
 - argon is inert and most of the air is inert.
- ___ 7. The main energy source that drives the systems like the hydrosphere, biosphere is
- the sun.
 - the moon.
 - the rotation of the Earth.
 - fossil fuels.
- ___ 8. This is the main energy source because
- the moon causes the tides.
 - the rotation of the Earth creates a large amount of kinetic energy.
 - fossil fuels are used in power plants and cars.
 - the sun emits large amounts of heat and light causing the water cycle and plant growth.
- ___ 9. Water moves slowly through a wetland into the plants and mud. In this way, wetlands act as natural
- filters.
 - habitats.
 - tributaries.
 - artesian wells.
- ___ 10. A wetland acts as...
- filters because some waste materials settle out, some wastes are absorbed by plants, and silt and mud is trapped by plant roots.
 - habitats because the water and plant and mud allow bugs to live.
 - tributaries because it catches all of the water from the rivers.
 - artesian wells because there is water flowing above ground.
- ___ 11. The atmosphere is
- the layer in which weather occurs.
 - the layer that contains the ozone layer.
 - the layer of water in the oceans.
 - the layer of gases that surrounds the Earth.

- ___ 12. The reason I believe the atmosphere is this layer is because
- the weather reporter always discusses the weather in the atmosphere.
 - the ocean has zones in which different sea creatures live called the atmosphere.
 - we live at the bottom of a blanket of air which as a whole is called the atmosphere.
 - ozone exists only in the atmosphere.
- ___ 13 The main layers in our atmosphere from Earth to outer space are:
- troposphere, stratosphere, mesosphere, thermosphere.
 - stratosphere, troposphere, mesosphere, thermosphere.
 - mesosphere, troposphere, stratosphere, thermosphere.
 - thermosphere, troposphere, stratosphere, mesosphere.
- ___ 14. The layers of the atmosphere are determined according to changes in
- altitude.
 - density.
 - pressure.
 - temperature.

Use the diagram to answer 15 and 16.



- ___ 15. This picture shows the
- rock cycle.
 - weather.
 - water cycle.
 - rain.
- ___ 16. This is because I see
- the raindrops coming from the cloud.
 - wind and the rain on the picture.
 - mountains being worn down by rivers and rocks moving to the ocean and into the clouds in a cycle.
 - the movement of water in a continuous cycle through the processes of evaporation and condensation.
- ___ 17. Which earth system is a plant considered a part of?
- geosphere.
 - biosphere.
 - atmosphere.
 - hydrosphere.
- ___ 18. Plants are included in this category because
- water travels through plants.
 - when they decompose they become part of the soil.
 - they breathe carbon dioxide in and oxygen out.
 - they are living organisms which require food, water and a healthy environment.
- ___ 19. The air on top of Mount Everest
- is hard to breathe because the pressure on the top of the mountain is very high.
 - changes depending on the weather.
 - is very hot.
 - is hard to breathe because lack of oxygen.
- ___ 20. This change in air happens because
- of the great density of air molecules creates high pressure.
 - the density of the air molecules decreases as you go higher into the atmosphere.
 - there are great snowstorms on the mountain with high winds.
 - it is closer to the sun so it must be warmer.

APPENDIX E

SAMPLES OF STUDENT WRITING

6th Grade rough draft with teacher feedback

Explanation: Did the water disappear after the rain? Where did the water go?

Claim:

The water does not disappear after it rains - it goes to a different part of the water cycle, such as?

Evidence:

Water is always in the water cycle. In our Mini Water Cycle experiment the water went

from in the soil to water vapor at the top of the bottle making it foggy.

It also condensed on the side of the bottle. This shows the water is always moving in

Do you have numbers to support this?

Reason:

The water isn't disappearing because it is always in a different part of the water cycle which never disappears. What is a cycle?

How does the Sun allow the systems interact?

what? explain what that means!

a light bulb with flags in the Sun. When in the sun the flags turned. When in the shade they didn't. This shows that the Sun makes wind. Another experiment

how?

that we did was we put a rock in the sun + a rock in the freezer. We found out that the rock in the Sun was easier to break. In the final experiment,

what system

we put a thermometer in the Sun + one in the closet. The one in the Sun was higher than the other one. This showed us that the Sun makes the atmosphere warmer.

what was higher? how?

* Reasoning: The Sun is a major power source.

how?

Without the Sun we would probably be frozen. Also, we wouldn't have any healthy plants + we wouldn't have the water cycle.

why?

This is why the Sun's roles are so important.

Claim: 3 → Great!

Evidence: 2 → use some of your class notes to improve your evidence

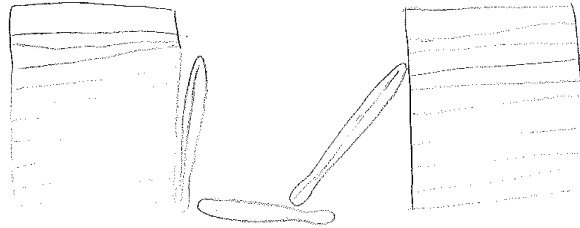
Reasoning: 2

6th grade final draft after teacher feedback

Claim: The sun has the role of being a power source to the *Hydrosphere*, *Atmosphere*, and the *Biosphere*. It just interacts with the *Geosphere*, heating it so people can live.

Evidence: I got my evidence from the experiments the class did. For example, one of the experiments we did to learn how the sun is a power source for the *Hydrosphere* was this. We filled two cups with water, and then placed one cup in the sun and the other in a closet. After sitting overnight for about ten days, when we looked in the closet all the water was still there, while the-cup-in-the-sun's water had all evaporated. This taught us to keep the *Hydrosphere* or water cycle moving we must have the sun. Another example would be, the sun is needed in the *Geosphere* so that things in the *Biosphere* stay alive. What we did to figure this out was: fill two cups with dirt. After filling the cups we put one in the sun and the other cup in a closet. Then, we left the cups sit about ten days. When we next looked at the cups, we saw the sun kept the dirt warm, but the dirt in the closet was cold. From this we learned the sun heats the *Geosphere* which keeps all living thing warm. The next example I have is this; we filled two clear jars with soil, planted seeds, watered them, and then finally covered the jars. Then we left them for about five days, one in the closet, and the other jar in the sun. By the end of the five days you could see the closet jar had plants, but they didn't look too healthy. Even though the closet plants grew, the sun plants didn't grow. We decided the sun plant probably didn't have enough water to grow this experiment taught us that plants need a certain amount of water to grow and the sun to make them healthy. My last example is for the *Atmosphere*. To learn what we did we had this experiment set up. Shine a desk lamp over three thermometers set so one is

laying flat, one is angled, and one up-and-down. (We used books to angle and hold up.) It looked like this:



From this we learned it is hottest where there is direct sunlight (the laying flat thermometer), and the coolest where there is practically no direct sunlight (up-and-down thermometer). So, depending on what angle sunlight goes through the Atmosphere that is how hot it is.

Reasoning: I believe the sun's roles are very important. Its roles are powering, helping powering, and heating the earth's systems. The ways it does this are; for the *Atmosphere* it travels through the *Atmosphere* heating it and then heating the earth. For the *Biosphere* the sun makes plants grow strong and healthy. The sun helps the *Hydrosphere* by making water do many things such as evaporate and condensate. Lastly is the way it powers the *Geosphere* is the sun heats the *Biosphere* and keeps living things alive. Because the sun's power does this the earth's systems interact by using the sunlight and causing a chain reaction. These are the roles of the sun in powering the earth's systems.

7th grade final draft after peer feedback

Claim: The Sun's role in the Hydrosphere, Biosphere, Geosphere and Atmosphere is many things such as being the power source in the water cycle, making plants grow healthy, making rocks erode faster and heating up the atmosphere.

Evidence: We know that the Sun plays all of these roles because we conducted many experiments. In our experiment for the Hydrosphere, we made two closed up jars with water and soil to represent the water cycle. We placed one jar in the Sun, and the other jar in the closet. After a couple days, we checked on the jars and recorded data on whether or not there was condensation. We found out that only the one in the Sun had condensation. This experiment showed us that the Sun powers the water cycle, and without the Sun, we wouldn't have rain, snow, ice and many other things. In the experiment we did for Biosphere, we made two more mini water cycles. In this water cycle we also added cat grass. We again placed one jar in the Sun and the other one in the closet. After a week, we checked on the water cycles and saw that the jar in the closet had more plants than the jar in the Sun. This happened because the plants in the closet just took the moisture from the soil and grew off of that. The plants were very white and sick. The jar in the Sun only had one blade of grass, but the blade was green and thick. This showed us that plants need the Sun to grow healthy. The next experiment that we did was for Geosphere. In this experiment, we put a rock in the Sun and a rock in the freezer. After the rocks had been in the freezer and Sun for about two hours, we hit each rock three times. We found out that the rock in the Sun had broken more. This experiment showed us that the Sun helps rocks erode faster. The last experiment that we did was for the Atmosphere. In this experiment, we put a thermometer in the Sun and a thermometer in the closet. We checked the thermometers at 10:30 am, noon, and 3:00pm. At 10:30 the thermometers were the same at 27 degrees Celsius. At noon, the one in the Sun was 31 degrees and the one in the closet was 29 degrees. At 3:00 the one in the Sun was 27 degrees, and the one in the closet was 26 degrees. This experiment showed us that the Sun helps heat the Atmosphere.

Reasoning: The Sun allows the Hydrosphere, Biosphere, Geosphere, and Atmosphere to interact in a complex way. If there wasn't a Sun, then the water cycle wouldn't be able to run. If there wasn't the water cycle, then the plants, animals and humans wouldn't have any water to drink. The water cycle also helps rocks in the Geosphere erode. Without the water cycle and heat from the Sun, the Atmosphere would be polluted and cold. This is why we need the Sun.