

THE EFFECT OF SCIENTIFIC EXPLANATION INSTRUCTION ON EXTENDED
RESPONSE PERFORMANCE BY EIGHTH GRADE SCIENCE STUDENTS

by

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ABSTRACT

This action research-based classroom project sought to discover if direct instruction of scientific explanation will improve student performance on extended response style questions. Students were taught to write a scientific explanation using Katherine McNeill's Claim-Evidence-Reason Framework. Student activities were scaffolded for increasing difficulty, culminating in an inquiry project requiring them to write a scientific explanation from data they collected. Eight of nine students in the research group showed improvement in scientific explanation writing skills. Students' confidence in their abilities to write explanations also improved.

INTRODUCTION AND BACKGROUND

I have been a science teacher at Bristol Middle School for two years. I have noticed that many of my students are not able to adequately interpret, analyze or explain the science they observe and/or take part in. They are very curious and enthusiastic about science. They love to participate in both guided and open inquiry. Through various teaching strategies, I feel my methods of inquiry and nature-of-science instruction are quite effective. My students are mostly active participants and remain on task throughout inquiry investigations. They ask great questions and are enthusiastic about designing investigations. However, when it comes to writing about science, their skills are lacking.

Bristol Middle School is in the small, rural town of Bristolville in the Northeast corner of Ohio. Our school houses all grades, from kindergarten to twelfth, under one roof. There are approximately 800 students. Students in our district are predominantly Caucasian, with a small number of African-American and Hispanic children. We have a few Amish students, some of which are English language learners.

Families in Bristolville are often single-parent families in the lower income bracket. About 60% of our students are on the free lunch program. Education is often not a top priority, as even food and clothing needs are sometimes not met. Employment is predominantly in the blue collar trades, however, dairy and grain farmers are also common. Because our school is so small, my students know each other quite well and often recall fond memories of their younger grades together. I feel this provides a sense of unity that is often lacking in larger schools. Drug, alcohol and violence problems are low, compared to some of the nearby inner-city schools.

Teaching and Classroom Environment

The inadequacies in my students' investigations arise when they try to explain the science they have discovered. Despite my attempts to elicit more thorough and thoughtful analyses from them, I frequently get very poor explanations or sometimes no explanation at all. In completing this action research-based classroom project, I researched, identified and employed methods for teaching my students to write exemplary scientific explanations. By doing so, I hoped to improve their ability to not only explain what they observe, but to effectively communicate it to others. An additional result I also hoped to find was higher scores for student extended responses on standardized tests.

Focus Question

The question I sought to answer with this project was: Will direct instruction of scientific explanation significantly improve my students' written explanations of scientific events? I also sought to answer the following sub-question: Will instruction in scientific explanation skills increase my students' confidence in writing extended responses?

CONCEPTUAL FRAMEWORK

Scientific literature that examines scientific explanation can be grouped in three categories for discussion. The first part of this conceptual framework addresses research that provides rationale for using science explanation to improve student learning. The second part presents frameworks that have been used for defining scientific explanation. The last part discusses articles that address methods for analyzing students' scientific explanations.

Why Teach Scientific Explanation?

For many years, science at the middle school level was taught using traditional laboratories for which students were given a list of procedures to follow with subsequent questions to answer. This is not how science is done by real scientists. To be effective in today's world, science instruction needs to focus on how scientists do real science (National Science Education Standards, 1996).

In 1996, The National Research Council (NRC) released the National Science Education Standards that changed the way science was to be taught. Subsequently, the Ohio Department of Education (2012) released the *Ohio Revised Science Standards and Model Curriculum; Grade PreK through Eighth* in which the following cognitive demands are listed:

Demonstrating Science Knowledge: Requires students to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about the relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments.

Interpreting and Communicating Science Concepts: Requires students to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technical knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios (ODE).

As a result of these state mandates, many teachers in Ohio have begun using inquiry-based methods for teaching science. Strategies for teaching science through inquiry generally include the following components; identifying a problem to be solved, listing ideas and conducting research about the problem, formulating a question to answer, writing a set of procedures to follow that will include data collection as evidence, analyzing the evidence, developing an explanation for relationships in the data and then sharing the explanations with others (Llewellyn, 2007). However, simply instructing them to develop an explanation and then put it in writing does not yield adequate results. Teachers, in a study by Sampson and Blanchard (2012), stated that integrating scientific argumentation in their courses would improve students' understanding of how scientists conduct science. However, the teachers in this study also identified obstacles for teaching scientific explanation that included lack of teacher training and preparation time. A specific set of criteria for teaching and evaluating scientific explanations is needed.

Direct instruction of scientific explanation often includes scientific argumentation as part of the process. By one definition, scientific argumentation is not a discourse made in anger over a difference of opinion, but rather a verbal or written defense on the part of the student for why their scientific explanation is sufficient (McNeill, 2011). In their study, McNeill and Martin discovered that the scientific writing abilities of Martin's fifth grade science students improved after engaging in a scientific explanation framework that included argumentation. In the process of defending their explanation, students' ideas about science solidified and their writing about science became more coherent.

Frameworks for Scientific Explanation

As stated earlier, adequate teacher training appears to be lacking for these fairly new standards. The literature reveals there are a variety of definitions of scientific explanation, all mostly similar in components, but varying in implementation. Identifying and outlining a few exemplars is the focus of this section.

One method for implementing scientific argumentation is called Argument-Driven Inquiry (ADI) and was developed and investigated by Sampson, Grooms and Walker (2012). ADI is a multi-step process that includes student participation in an investigation, data collection and an explanation of relationships within the data. A hallmark of ADI is the employment of peer-review and an argumentation session of students' written reports about the investigation. Sampson, Grooms and Walker found that students' abilities to write explanations improved after engaging in ADI over the course of several weeks. In addition, the authors noted that at the beginning of the treatment, students were more likely to just go along with the prevailing thoughts of the group rather than oppose an idea that they weren't sure was correct. At the end of the study, students were more likely to discuss and oppose prevailing opinions after engaging in the treatment.

McNeill (2011) investigated the Claim-Evidence-Reason (CER) method for teaching scientific explanation in a fifth grade science class. Results showed that by the end of the school year students were able to write a better structured scientific explanation. McNeill has since co-authored a book on the use of the CER framework to teach scientific explanation in the middle grades. In the book, the authors contend that developing finesse in scientific explanation is a gradual process (McNeill and Krajcik,

2012). The authors state “But all students can construct strong scientific explanations when they are provided with sufficient time, practice and instructional support” (p. 7).

A third study identified a fourth component to a well-crafted scientific explanation. The authors claim that students need to be able to provide a rebuttal that challenges the claim made (von Aufschnaiter, Erduran, Osborne and Simon, 2008). They identified the process of developing a rebuttal as a much more complex skill and one which requires the student to truly understand the science concepts being addressed. During discussion and argumentation of their scientific explanations, students craft a rebuttal to challenges and opposition. It is during this step that true meaning is made by all students involved.

Berland and Resier (2009) identified three goals of a scientific explanation; “making sense, articulating and persuading” which correlate to instruction using the CER Framework. Results of their study showed that students have the greatest difficulty attaining the third goal of “persuasion.” Berland and Reiser believe the reason for this weakness in persuasion is due to the traditional nature of most science classrooms, in which students are rarely, if ever, required to persuade anyone of anything. They contend that science educators should develop scientific explanation activities in which the goal of persuasion is highlighted. This may provide the additional emphasis and motivation for the development of this important skill used by real scientists to do real science.

From the literature it is clear that there are some basic components of a well-written scientific explanation. The CER Framework seems the most teacher-friendly, although all are very similar.

Methods for Evaluating Students' Use of Explanation

Analyzing student work had the purpose of project assessment for efficacy, student assessment (both formative and summative), and teacher assessment for instructional technique and methodology. One method for assessing students' scientific explanation is the Evidence-Based Reasoning Assessment System (EBRAS), (Brown et al, 2010).” The authors of this case study wished to provide an example of the usefulness of EBRAS. EBRAS makes use of a four part evaluation process: 1. Construct map (tool for evaluating responses along a continuum), 2. Items design (a design method with the express purpose of eliciting a specific response), 3. Outcome space (a collection of possible responses and their value on the construct map) and 4. Measurement model, chosen to statistically analyze responses. I found step three of this process to be especially relevant to my project. An “outcome space” lists the variety of possible responses by students and assigns them a value for scoring purposes. Responses are categorized with different categories having higher or lower values. For example, a response that shows a student made connections between two or more concepts when supporting their explanation would have a higher value than an explanation that only used one concept for support. Anticipating my students' responses and pre-assigning values to those responses made evaluation easier, however there were still responses that I did not anticipate and had to assign a value after the assessment.

Several of the articles reviewed the use of pre- and post-assessments. Sampson, Grooms and Walker made use of this strategy in their ADI study (2012). Students were given a pre-assessment before participating in ADI. This pre-assessment consisted of a performance task in which small groups of students were shown a discrepant event and

asked to write a scientific explanation for what they observed. At this point students had not been instructed in scientific explanation and received no support from the teacher. Student responses were recorded and evaluated. The students then participated in the ADI treatment throughout the school year. At the end of the treatment, students completed the exact same performance task as a post- assessment. By using the same task as a pre- and post-assessment, more reliable comparisons can be made.

Von Aufschnaiter and coauthors (2008) used a coding scheme to evaluate the quality of every statement made during students' scientific arguments. Student sessions were video and audio recorded and each individual statement assessed. First it was determined if the statement justified the students' claim. Then, if present, the quality of the justification was gauged and assigned to one of three levels of abstraction. This method of evaluation provides great detail for the researcher, but also requires a great deal of time for individual statement analysis.

In summary, a review and analysis of literature revealed that encouraging scientific explanation and argumentation in the science classroom leads to improvement in both understanding and ability to verbally and orally defend a scientific claim. There are a variety of methods teachers can use to provide instruction in this important science process skill. Evaluation of student improvement in scientific explanation is challenging, but can be achieved with sufficient forethought and preparation.

METHODOLOGY

The purpose of this action research-based classroom project was to improve student ability to write scientific explanations. Specifically I investigated the effectiveness of direct instruction of scientific explanation for improving analysis of

scientific events. I also wished to determine if instruction of scientific explanation improves student confidence in writing extended responses on standardized assessments. The investigation was conducted in my eighth grade science classes in February and March of 2014.

Participants

The participants of this action research project included 52 students in three sections of eighth grade general science. A research group of nine students were chosen from the whole group for pre-survey and assessment, post-survey and assessment and post-interviews. This research group was randomly chosen, three each from three subgroups identified by the Ohio Department of Education's Educational Value-added Assessment System ($N=9$). The subgroups are based on previous standardized test scores and are categorized as "likely to pass" the next round of standardized tests (Group A), "at risk of failing" the next round of standardized tests (Group B) and "unlikely to pass" the next round of standardized tests (Group C). I chose three from each subgroup as I wanted to compare growth among the three levels. Random sampling was performed by drawing student names from a container.

The three classes had just finished a unit on plate tectonics and were beginning a unit on force, motion and the Law of Conservation of Energy. The three class sections were about equal in every demographic. The ratio of males to females was about one to one. Each section had one or two gifted students and each section had four or five students who love science, as indicated on a start of year interest survey. The only exception was that the third section had a bigger proportion of students with an Individual Education Plan (IEP), receiving assistance from an intervention specialist. In this section,

there were eight students who had IEPs and four who did not. The intervention specialist was present in the room every other day with this section. She assisted not only the students with IEPs but the other students as well.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

Intervention

For this action research-based classroom project I proposed to use McNeill and Krajcik's (2012) framework for teaching scientific explanation with middle school aged students. Students participated in three activities that required them to initially evaluate scientific explanation, and ultimately write scientific explanations of their own. Evaluating these explanations required a rubric that was detailed and concise but also suitable for use in my classroom and with my students (Appendix A). It also needed to reflect the goals of the *Ohio Revised Science Standards and Model Curriculum*.

The pre-assessment was conducted before direct instruction of scientific explanation. It began with a narrative about two students investigating earthquakes and included a complete data set. Students were asked to write a scientific explanation that addressed the question "How does the number of seconds between the arrival time of the S and P waves at the seismology station affect the Richter scale reading?" using the data from the narrative. This question was modeled after a typical extended response question students are asked on the OAA. I chose plate tectonics as the content for this assessment as it was to be administered after finishing our plate tectonics unit. I didn't want to bias the

assessment by asking students to write an explanation for which they had inadequate content knowledge.

The pre-assessment was then followed by whole class instruction in scientific explanation. The instruction and subsequent activities took place in conjunction with a unit on energy, force and motion. McNeill and Krajcik's (2012) framework was used to explain the components of a well written scientific explanation. The first component is a Claim. A Claim is an answer to the question asked or a statement that describes the phenomenon that occurred. The second component is Evidence. In a well written scientific explanation, specific data is presented and linked to the Claim as Evidence that the Claim is accurate. The data needs to be appropriate to what is being claimed, but also in adequate amount. Evidence is details from the investigation, without any interpretation from the writer. The third component of a scientific explanation is Reason. The Reason tells how the Evidence supports the Claim that was made. Scientific principles are presented and used as part of this support in the Reason. Students also reviewed a rubric that was be used to evaluate scientific explanations.

After the above instruction, all students participated in three activities. In the first activity, students were asked to critique a series of pre-made explanations of varying quality. Each explanation was written in response to a narrative about an investigation performed by two fictitious students, John and Mary. In the investigation, John and Mary compared the effects of temperature on the bounce height of tennis balls. Their data set is then presented, followed by four scientific explanations for the investigation. Students were then asked "Which of the following statements best provides a scientific explanation for the data John and

Maria collected?” Students were also asked to justify why their choice was the best. This justification served as a formative assessment.

In the second activity, students participated in a cooperative group activity that asked them to write three scientific explanations, given three narratives of an investigation and a corresponding data set. The class was broken into groups of two. Each small group was given the three narratives and asked to write a scientific explanation that addressed a specific question about the narrative. Once completed, groups were paired together and asked to choose the best explanations for each narrative. This required students to critique the other group’s explanations, and defend their own. Finally, explanations chosen as the best for each narrative were presented and critiqued, using the rubric, in a whole class discussion.

The third activity made use of scientific inquiry. Students were first presented with a demonstration of a pendulum built from string and large washers. They were then broken up into small groups of three or four and allowed to build and explore the actions of their own pendulum. They were then instructed to design an investigation to answer the question “how does changing the length or mass of the bob affect the period?” Students carried out their investigations and collected data in a data table of their own design. Students were then asked to write a scientific explanation for their data, using the rubric. These explanations were collected and evaluated by me as an additional formative assessment. My data collection instruments are summarized in Table 1.

Table 1
Data Triangulation Matrix

<i>Focus Questions</i>	<i>Data Source 1</i>	<i>Data Source 2</i>	<i>Data Source 3</i>
<i>Primary Question:</i> Will direct instruction of scientific explanation significantly improve my students' written explanations of scientific events?	Pre intervention extended response writing activity	Post intervention extended response writing activity	Teacher journal
<i>Secondary Question:</i> Will instruction in scientific explanation skills increase my students' confidence in writing extended responses?	Pre intervention survey with attitude scale	Post intervention survey with attitude scale and interview	Teacher journal

After the third phase of the whole class instruction, the research group participated in a post-survey and assessment, as well as a post-interview. The post-survey and assessment were identical to the pre-survey and assessment, with one exception. There was a typographical error on the pre-survey that was not detected until after it was administered. This error was corrected on the post-survey, however, data collected from this question will not be considered valid due to the error. All other survey questions, along with the assessments were analyzed and compared. Summative evaluation of the assessments was performed using the CER/OAA hybrid rubric (Appendix A).

An informal post-interview was also conducted. My intent for the post-interview was to gauge if students felt the scientific explanation instruction helped increase their

confidence for taking the OAA. I was also curious if students had other ideas or thoughts about the activities that they did not write when completing the survey.

Timeline

February 17 to 21, 2014:

Phase 1. Pre-assessment was conducted. In the pre-assessment, students were given an easily interpreted data set using plate tectonics content. They were asked to write an explanation for the data. These assessments were then evaluated using a CER/OAA extended response rubric hybrid. The survey then followed, asking students to describe what should be included in a scientific explanation and to rate themselves on their confidence and abilities to write a scientific explanation. (See Appendix B) I tracked anecdotal events and observations in a teacher journal regarding students' responses.

February 24 to 28, 2014

Phase 2. Activity 1 – Comparing scientific explanations

Students were given a scientific investigation scenario that included a data set and four pre-written scientific explanations for the data. (See Appendix D) They worked in cooperative groups to evaluate the explanations using the CER/OAA hybrid rubric and to choose which of the explanations was best. . (See Appendix A) Direct instruction of the CER framework then occurred. Students were asked to review the explanations and modify their original choices for best explanation, if necessary. The activity culminated with a group discussion of which explanation was best and why. I continued to track anecdotal

events and observations in a teacher journal regarding students' reactions and behaviors throughout the activity.

March 3 to 7, 2014:

Phase 3. Activity 2 – Practicing CER using data sets

Students were given a scientific investigation scenario that included a data set. They worked in cooperative groups to write an explanation for the data using the CER framework. Students then peer-reviewed each others' explanations using the CER/OAA hybrid rubric. Students made suggested improvements to their scientific explanations, if necessary. An exit ticket served as a formative assessment, asking students to identify the most important concept of the lesson. I continued to track anecdotal events and impressions in a teacher journal regarding students' reactions and behaviors throughout the activity.

Phase 4. Activity 3 – Practicing CER using student-generated data sets

Students participated in an inquiry investigation that addressed one of two of the following guiding questions; "how does changing the mass of the pendulum's bob affect the period?" or "how does changing the length of the pendulum's arm affect the period?" Groups chose which guiding question to investigate. They worked in cooperative groups to design and carry out their investigation. They collected quantitative data and each student then used it to write a scientific explanation using CER that addressed their guiding question. This explanation was then evaluated by me using the rubric to gauge if further CER instruction was needed. I also tracked anecdotal events and impressions in a teacher journal regarding students' reactions and behaviors throughout the activity.

March 10 to 19, 2014:

Phase 5. The post-assessment and survey were conducted using the same prompt and survey questions as in Phase 1. (See Appendix B) Approximately one week later, a short interview was conducted with each student (See Appendix C). Anecdotal events and impressions were once again recorded in a teacher journal regarding students' responses.

DATA AND ANALYSIS

This action research-based classroom project sought to discover if direct instruction of scientific explanation would improve student confidence and performance on extended response style questions by collecting data using a variety of triangulated sources. These sources consisted of a pre and post unit assessment and survey, a post unit interview and teacher observations and impressions recorded in a journal. Data was collected on a research group of nine randomly chosen students, three each from three academic levels as determined by Ohio Department of Education's Educational Value-added Assessment System ($N = 9$). All nine students were members of classes that participated in the direct whole-class instruction of scientific explanation using the CER framework and the scaffolded activities outlined in the methodology.

Effects of Direct Instruction on Explanations

The first question I sought to answer was "Will direct instruction of scientific explanation significantly improve my students' written explanations of scientific events?" Three pieces of evidence allow me to conclude that my

students' written explanations did improve after the direct instruction. This evidence consists of the pre-assessment, the post-assessment, and observations I made both during and after the direct instruction.

The students' abilities to write a scientific explanation for presented data were evaluated both before and after the direct instruction of the CER framework using the OAA hybrid rubric. Overall, the scientific explanations written by my students improved after instruction of the CER framework. Eight out of nine students' scores increased between the pre-assessment and the post-assessment. The mean score for the pre-assessment was 20.4%. During the pre-assessment, three students had no response to the question and the highest score of students who did respond was 67%. After direct instruction, the same assessment was used again in the post-assessment. The mean score for the post-assessment was 67%. An increase from 20.4% to 67% is noteworthy. Only one student had no response on the post-assessment, and three students scored 100%. All results are shown in Table 2.

Table 2
Results of Written Assessments

<i>Student</i>	<i>PreAssesement Score</i>	<i>PostAssessment Score</i>
Group A Student 1	No Response	100%
Group A Student 2	67%	100%
Group A Student 3	33%	67%
Group B Student 1	0%	83%
Group B Student 2	50%	100%
Group B Student 3	No Response	50%

Group C Student 1	No Response	No Response
Group C Student 2	17%	67%
Group C Student 3	17%	33%

It is interesting that all three subgroups showed improvement. In Ohio, school improvement is evaluated not only on percent passage rate, but also on improvement shown by all subgroups. Direct instruction of scientific explanation may help my students in all subgroups pass the OAA. Figures 1, 2 and 3 provide examples of student writing from all three subgroups.

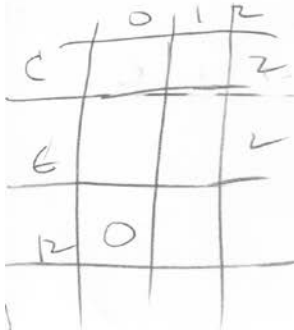
In addition to improvement between the pre and post assessments, I also made note of improvement during whole-class instruction in my journal. The first phase of the instruction consisted of students evaluating prewritten scientific explanations. Students seemed initially reticent to critique the explanations during class discussion. They recognized that certain explanations were inadequate but could not provide a rationale. After this phase, direct instruction occurred, with clarification of the CER framework. We then went back and re-evaluated the pre-written explanations, looking for weaknesses. More students could then verbalize that the best explanation cited actual evidence from the data table. Pointing out a weakness, one student stated “Saying “a lot” and “not very much” means different things to different people.” Interestingly, during the post interview, four of the nine students felt this activity was the most helpful in understanding scientific explanation. I did not expect this. I thought they would identify the inquiry

activity as the most helpful, simply because my students frequently tell me they learn best during hands-on activities.

Other evidence that supports my claim comes from the pre and post surveys and the post interview. On the pre-survey, none of the nine students surveyed could successfully answer the question “what does a scientific explanation consist of?” After the direct instruction, five of the nine students were able to successfully answer the question, with others at least partially successful. This implies that when writing an explanation of their own, they would know the important components to include.

AZ PRETEST

4/6



Write a scientific explanation that Mary can use to answer John's question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

The further away the epicenter, the greater the time difference is between P waves and S waves. When it was 590 km away, the diff. was only 1 min, when the epicenter was 4000 km away, the diff. was 4 min. greater.

6/6

Distance of seismology station from earthquake's epicenter	Time between arrival of primary and secondary waves at the seismology station
4000 km	5 minutes
3000 km	4 minutes
2000 km	3 minutes
1000 km	2 minutes
590 km	1 minute

AZ POST-TEST

Write a scientific explanation that Mary can use to answer John's question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

The further away the epicenter is from a seismology station, the greater time difference between P waves and S waves. When the seismology station was 4000 km, 3000 km, 2000 km, 1000 km, and 590 km away, the time difference was 5 min, 4 min, 3 min, 2 min, and 1 min. As the distance increases, so does the time intervals.

Figure 1. Example of a Group A Student's Pre and Post Responses.

(3/6)

B2 PRE TEST

Write a scientific explanation that Mary can use to answer John's

question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

	0	1	2
C			1
E			
P		1	

The distance is related to the time interval because the less minutes the lower the distance is, and it looks like for every 1 minute it goes down 1000 km is taken away.

6/6

Distance of seismology station from earthquake's epicenter	Time between arrival of primary and secondary waves at the seismology station
4000 km	5 minutes
3000 km	4 minutes
2000 km	3 minutes
1000 km	2 minutes
500 km	1 minute

B2 POST TEST

Write a scientific explanation that Mary can use to answer John's

question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

	0	1	2
C			2
E			2
P			2

The distance from the epicenter is related to the time interval between the arrival of the waves because as the distance goes down, the amount of time goes down also. The distance goes from 4000 to 500 and as this goes down the time goes from 5 to 1 minute.

So as the distance goes down the time also goes down.

Figure 2. Example of a Group B Student's Pre and Post Responses.

0 1 2
C
6 ✓
M ✓

$\frac{1}{6}$

C2 Pre-Test
Write a scientific explanation that Mary can use to answer John's question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

The epicenter is related to the interval because, P waves move faster than S waves

1000 km	2 minutes
590 km	1 minute

$\frac{4}{6}$

C2 Post-Test
Write a scientific explanation that Mary can use to answer John's question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

Claim: The distance from the epicenter is related to the time interval between the arrival primary and secondary are, they are both increaseing.

Evidence: 590 km in 1 minutes
1000 km in 2 minutes
2000 km in 3 minutes

Reason: Has the distance in the epicenter increases so does the primary and secondary waves at the seismology station.

Figure 3. Example of a Group C Student's Pre and Post Responses.

Effects of Direct Instruction on Student Confidence

The second question I sought to answer was “Will instruction in scientific explanation skills increase my students’ confidence in writing extended responses?” There are three pieces of evidence that allow me to claim that my students gained confidence in their extended response writing skills. Included in this evidence are the pre-survey, the post- survey as well as the post-interview. Additionally, observations from my journal support this evidence. However, evidence is inconclusive regarding a transfer of that confidence to doing well on the OAA.

Results of both the pre- and post-survey and the post interview indicate that students do feel more confident in writing scientific explanations but not in answering extended response questions on the OAA. Questions 5 through 7 in the survey were Likert scale questions asking students to rate their confidence in various aspects of scientific explanation. On Question 5 “How confident are you in making a scientific claim?” seven of the nine students increased in confidence between the pre-survey and the post-survey. On Question 6 “How confident are you in using scientific evidence to support a claim?” five of the nine students showed an increase in confidence. On Question 7 “How confident are you in stating a scientific reason that links evidence to a claim?” again five out of nine showed an increase in confidence. This data shows that over half the students gained confidence in writing all three aspects of scientific explanation.

Question 8 of the pre- and post-surveys was a Likert scale question as well, and asked the question “How confident are you in doing well on OAA science

extended response questions?” Only three of the nine showed an increase in confidence. Other responses to this question showed another three students remained the same in confidence level and three actually showed a decrease in confidence level. However, during the post-interview I asked the related question “Do you feel the scientific explanation activities we did in class will help you do better on the OAA?” All nine students responded yes to this interview question. Therefore, I feel results were inconclusive regarding student confidence in answering extended response questions on the OAA. Table 3 shows data from the pre- and post-survey.

Table 3
Results of Survey, Questions 5 through 7

	<i>Change in Confidence Level</i>	<i>Total all groups</i>
Question 5 Group A	2 increase in confidence 1 same confidence level 0 decrease in confidence	7 increase in confidence 1 same confidence level 1 decrease in confidence
Question 5 Group B	3 increase in confidence 0 same confidence level 0 decrease in confidence	
Question 5 Group C	2 increase in confidence 0 same confidence level 1 decrease in confidence	
Question 6 Group A	3 increase in confidence 0 same confidence level 0 decrease in confidence	5 increase in confidence 2 same confidence level 2 decrease in confidence
Question 6 Group B	0 increase in confidence 2 same confidence level 1 decrease in confidence	
Question 6 Group C	2 increase in confidence 0 same confidence level 1 decrease in confidence	

Question 7 Group A	2 increase in confidence 1 same confidence level 0 decrease in confidence	5 increase in confidence 2 same confidence level 2 decrease in confidence
Question 7 Group B	2 increase in confidence 1 same confidence level 0 decrease in confidence	
Question 7 Group C	1 increase in confidence 0 same confidence level 2 decrease in confidence	

Additional support for claiming my students' confidence increased comes from one post-survey response for Question 12 "Is there anything else I should know?" A student from group B wrote the statement "I feel much more confident making a scientific explanation now." This student is one with an IEP and in the past has routinely shown to lack confidence on other tests and quizzes. After one test on which she scored quite well, she expressed complete surprise at her performance. I am pleased to see her develop more confidence in herself and feel it will help her when she takes the OAA. As a middle school teacher, one of my goals is to help my students avoid test anxiety. Many of them tell me their minds "lock up" when taking tests. Scientific explanation instruction may help alleviate this test anxiety for at least some of my students.

An entry from my journal provides further evidence that student confidence increased. When I initially asked the nine students to participate, I noticed some hesitation. Later, when I handed out the pre-survey, one student stated "But what if I mess up?" I assured them the survey would not count against their grade, but the student still seemed worried. I noticed no such uncertainty when I administered the post-survey. None of the nine students showed any

hesitation, and a few even seemed happy to participate in the post-survey. The student that was worried about “messaging up” even bragged to the other students that he was helping me with my college research. I attribute this change in attitude at least partly to the direct instruction of scientific explanation. A distinct but simple list of components to include when answering an extended response questions allows students to approach such questions with clarity and self-assurance.

Unexpected Results

An unexpected and positive impact of scientific explanation instruction resulted a few weeks after the unit had ended. I was administering a mid-semester assessment using released questions from prior OAAs. I had used the same assessment at the beginning of the year. One extended response question asked for an evaluation of a scientific claim made by a group of fictitious students who had studied butterflies in their school yard. In their response, students were to provide two reasons the conclusion was not scientifically valid. On the beginning of the year assessment, not a single student stated that the group lacked evidence in their claim. On the second assessment, 29 of my 54 students correctly identified that the group had not provided evidence as part of their conclusion. I consider this an important development and one that provides additional evidence that direct instruction of scientific explanation did indeed improve my students’ abilities to write explanations of scientific events. Figure 4 provides examples of student responses to this question, one of which was a participant in the research group and another with an IEP.

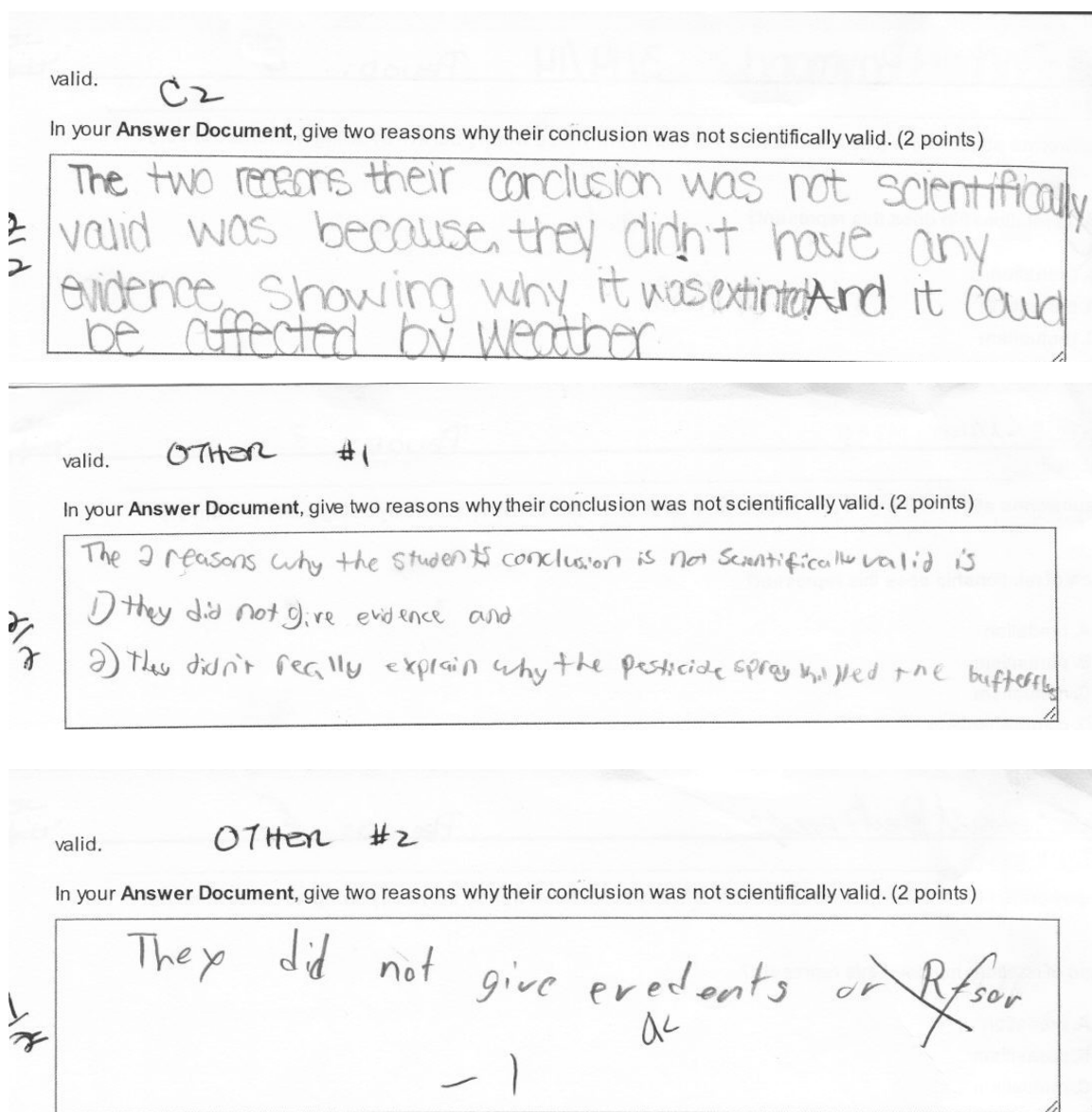


Figure 4: Examples of Student Writing on a Released OAA Extended Response Question.

INTERPRETATION AND CONCLUSION

This project provides evidence that direct instruction of scientific explanation improves students' abilities to adequately explain scientific concepts and phenomena. Students reported that their confidence in writing scientific explanations also increased.

Results were inconclusive if the gain in confidence would be reflected by standardized test scores.

Prior to the project, students' writing about scientific data they collected or observed was generally haphazard and unorganized. While there were a few students who were already gifted writers and could adequately explain the science they witnessed, for many students this was not the case. In response to my request for a summary of a laboratory activity, student work was often incomplete and sometimes not performed at all. My perception was that students found scientific explanation too difficult, too obscure and too undefined. This project allowed me to address this issue by providing a short, precise framework for students to follow when required to explain science.

Comparison of the research groups' pre-assessment writing to their post-assessment writing showed a marked improvement ($N=9$). Using the Scientific Explanation Rubric for evaluation, none of the students were able to earn the highest score of "6" on the pre-assessment and only one of the nine received a score of "4". After the project activities, three of the students in the research group provided a full evidence-based explanation and scored "6" on the rubric, while six of the nine scored "4". Perhaps the biggest improvement of all was in adequately citing evidence. McNeill (2009) states that "one of the key characteristics of science is its use of scientific data as evidence to understand the natural world." I consider evidence to be the hallmark of scientific explanation. Only one of the nine students cited evidence on the pre-assessment, while seven cited evidence on the post-assessment. I find this an outstanding result and consider this project a success because of it. Further support of this claim

comes from an increase by 54% of students who correctly stated that lack of evidence made a conclusion invalid on an OAA style extended response practice problem.

This project allows me to claim that direct instruction of scientific explanation also improves my students' confidence in writing such explanations. As shown by their responses on the pre-surveys and post-surveys, seven students in my research group gained confidence in their ability to make a claim, five students gained confidence in their ability to cite evidence that supports a claim and five students gained confidence in the ability to provide a reason that links the evidence to the claim. I find these results outstanding, simply because test anxiety and lack of confidence is so prevalent in middle-school age children. So many of my students claim, "I am just not good at science." They want to improve, but are not sure how. The CER framework provided an easy to follow method for writing an explanation. The framework is also simple enough to easily remember. Comments such as "This is easy" were overheard by me as we participated in the project activities. If I can help my students feel that they can be successful in science, I am doing them a great service.

I wish I could claim that students gained confidence in performing well on the OAA as well, however, survey results do not support this. While three of the nine students in the research group indicated that they gained confidence, three others indicated that they actually decreased in confidence. A possible explanation for these results is that the OAA is a high-stakes test, at least for teachers, and much pressure is put on students to perform well. Many students feel apprehensive about taking the OAA, often stating how much they hate them. As the school year progresses and we get closer to the test date, anxiety on everyone's part increases. Teachers begin reviewing, recalling

the reality of the test more frequently and giving additional homework. Correspondingly, students become more anxious as well. This increased anxiety may have been reflected in the post-survey, as it was given closer to the OAA test date than the pre-survey. Students undoubtedly had already started to feel the pressure of these important tests when the post-survey was taken.

VALUE

This action research-based classroom project has several implications for change in my strategies for teaching and in my classroom culture. I also made some unexpected discoveries as the project progressed, all of which will impact me as a teacher.

The most rewarding pedagogical discovery that I gained from this project was that I have the power to improve student writing skills. As a fifteen year veteran of math and science teaching, I have always felt my strength as a teacher lies in the more technical, process-oriented side of knowledge acquisition and less so on language arts. While I recognized the deficiency in my students to write about the science they were experiencing, I failed to recognize that I was the best teacher to attend to that deficiency rather than their language arts teacher. It was outside my area of expertise, and so I felt uncomfortable teaching writing skills.

By creating the project's series of scaffolded activities, I found that I was able to help my students learn a simple, three-step science explanation process, the CER Framework. The CER framework is rudimentary, and certainly scientific writing is much more complicated than a three step process, however, it is ideal for this age of students who are just learning to identify and describe "scientific data as evidence to understand the natural world (McKniell, 2009)"

One activity that I found particularly successful occurred during the first phase of the project. Students were given prewritten scientific explanations of various quality and asked to work in groups to critique and evaluate them. I believe this activity allowed them to experience and appreciate how difficult it can be to understand the intent of a writer, when the writing is inadequate or incomplete. So often this was the case with their own written explanations. In the post-interview, the majority of the students in the research group stated that this activity was the most helpful. I have used one or two activities in the past that make use of the strategy, but never realized that the students found this so beneficial. Other student writing could be improved this way as well, including writing scientific procedures and data analysis. In addition, I found this activity to be a great segue to the peer-review that was part of the activities in the second phase of the project. I was able to review the difference between constructive criticism and destructive criticism before students evaluated the writing of their partner.

The series of activities were so effective, in my opinion, that I will incorporate them yearly into my eighth grade science classes, and will begin developing similar activities for my seventh grade science classes. As noted in my journal, one student even said “I wonder if we can use this in math?”

Regarding student confidence, it was interesting that students felt more confident in writing explanations only for me, and not for the OAA. As teachers it is easy to overlook the anxiety students feel regarding standardized tests. At my and other teachers' suggestions, my school is taking steps to alleviate students test anxiety on the OAAs. These steps include providing water and snacks during testing, as well as

periodic breaks to stretch and walk around. I will also reconsider my OAA review emphasis and strategies to minimize student apprehension.

I would like to expand on the project next year by incorporating opportunities for students to challenge the explanations of others and then formulate a rebuttal. Formulating a rebuttal requires students to verbally defend their explanations the same way scientists do in the real world. Rebuttal requires students to consider alternative explanations and accept, refine or reject them (McNeill, 2009). McNeill states “Often in science there are multiple plausible explanations for how or why something occurred. Scientists consider and debate these multiple possibilities.” I believe engaging in rebuttal will help my students hone their reasoning skills, the part of the framework they had the most difficulty with. I would also like to work with science teachers in other grades to develop a consensus regarding a well written explanation. It would be interesting to see what other teachers believe are the important components of a scientific explanation. I feel we would all have notable differences in our ideas, enough to make discussing them worthwhile.

One last resolve is the continuation of a change I began making several years ago. I will continue to realign my teaching strategies to incorporate more science by inquiry. Scientific inquiry not only causes my students to be creative problem solvers, it also gives them the best opportunity to perfect their scientific explanation writing skills.

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APPENDICES

APPENDIX A
SCIENTIFIC EXPLANATION RUBRIC

SCIENTIFIC EXPLANATION RUBRIC

	0	1	2
Claim	Student did not make a claim.	Student made a claim, but claim did not address the question.	Student made a claim that addressed the question.
Evidence	Student did not cite data from the table.	Student cited data from the table but it did not support the claim.	Student cited data from the table that supported the claim they made.
Reason	Student did not state a reason.	Student stated a reason, but it did not link data to the claim.	Student stated a reason that linked the data to the claim they made.

APPENDIX B

CER PRE-ASSESSMENT AND POST-ASSESEMNT

CER PRE-ASSESSMENT AND POST-ASSESSMENT

Name: _____

John and Mary are in Mrs. Dobson's 8th grade science class. John was asked to investigate how distance from the seismology station to the epicenter of an earthquake is determined from the arrival time of the seismic waves at the station. John collected the following data about a few earthquakes and has asked Mary to help him make sense of the data.

Distance of seismology station from earthquake's epicenter	Time between arrival of primary and secondary waves at the seismology station
4000 km	5 minutes
3000 km	4 minutes
2000 km	3 minutes
1000 km	2 minutes
590 km	1 minute

Write a scientific explanation that Mary can use to answer John's question "How is the distance from the epicenter related to the time interval between the arrival of the primary and secondary waves at the seismology station?"

APPENDIX C

PRE-TREATMENT AND POST-TREATMENT SURVEY QUESTIONS

PRE-TREATMENT AND POST-TREATMENT SURVEY QUESTIONS

Student name: _____

****Please note: This interview is completely voluntary and will in no way affect your grade or class standing****

1. What is a scientific explanation?
2. Who makes scientific explanations?
3. When are scientific explanations made?
4. What does a scientific explanation consist of?

5. On a scale of 1 to 5, how confident were you in making the scientific explanation asked for in John and Mary's Earthquake investigation on page 1?

(circle one)

- 1 (Not confident)
- 2 (A little confident)
- 3 (Somewhat confident)
- 4 (Mostly confident)
- 5 (Very confident)

6. On a scale of 1 to 5, how confident are you in making a scientific claim? (circle one)

- 1 (Not confident)
- 2 (A little confident)
- 3 (Somewhat confident)
- 4 (Mostly confident)
- 5 (Very confident)

7. On a scale of 1 to 5, how confident were you in using scientific evidence to support a claim? (circle one)

- 1 (Not confident)
- 2 (A little confident)
- 3 (Somewhat confident)
- 4 (Mostly confident)

5 (Very confident)

8. On a scale of 1 to 5, how confident are you in stating a scientific reason that links evidence to a claim? (circle one)

1 (Not confident)

2 (A little confident)

3 (Somewhat confident)

4 (Mostly confident)

5 (Very confident)

9. On a scale of 1 to 5, how confident are you in doing well on OAA science extended response questions? (circle one)

1 (Not confident)

2 (A little confident)

3 (Somewhat confident)

4 (Mostly confident)

5 (Very confident)

10. What activity might help you develop more confidence in doing well on OAA science extended response questions?

11. Do you think the Scientific Explanation activities we have recently completed in science class have helped you write a better extended response to the practice OAA questions I assign, as compared to the beginning of the year? (*post-interview only*)

12. Is there anything else I should know?

APPENDIX D
INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

1. Do you think the Scientific Explanation activities we conducted in class will help you on the OAA?
2. Which part of the Scientific Explanation activities we conducted in class was most helpful?
3. Can you think of anything else I can do in class that will help you on the OAA?

APPENDIX E

ACTIVITY 1 – COMPARING SCIENTIFIC EXPLANATIONS

ACTIVITY 1 – COMPARING SCIENTIFIC EXPLANATIONS

Name: _____ Period: _____

Scientific Explanations

1. Read the following story:

Maria and John play tennis three times a week. In October, John noticed that their tennis balls did not bounce as high as they did in July. Maria wondered if this had anything to do with the weather. They conducted the following experiment to test if temperature was affecting the bounce of the tennis balls. They wanted to know “does temperature affect how high a tennis ball bounces?”

They bought two new cans of tennis balls (three in each can) of the same type and brand. They placed one can in the freezer and left one can on Maria’s kitchen table. The next day they removed the can of tennis balls from the freezer and Maria immediately dropped each ball from the same height on the same surface. John measured the first bounce of each tennis ball. The following table displays the data the friends collected.

<i>Trial</i>	<i>Height of bounce of tennis balls from freezer</i>	<i>Height of bounce of tennis balls from table</i>
1	43 cm	98 cm
2	38 cm	90 cm
3	51 cm	105 cm

Which of the following statements best provides a scientific explanation for the data John and Maria collected?

- A. Yes, John is correct. In all three trials, the warm tennis balls bounced higher. Warm temperature tennis balls will bounce higher than cold temperature balls. This is because cold tennis balls have less elastic energy than warm tennis balls.
- B. Cold tennis balls have a smaller bounce than warm tennis balls. The table shows that the cold tennis balls did not bounce very much and the warm tennis balls bounced a lot. The data shows that cold temperatures will cause tennis balls to have a smaller bounce than warm temperatures.
- C. Cold temperatures can cause tennis balls to have a smaller bounce than warm temperatures. The cold tennis balls bounced 43 cm, 38 cm and 51 cm. The room temperature tennis balls bounced 98 cm, 90 cm and 105 cm. The evidence shows the warmer tennis balls bounced much higher in all three trials. The cold causes the cold tennis balls to have less elastic energy than the warm tennis balls.
- D. Playing tennis in July causes tennis balls to bounce higher than when playing tennis in October. The table shows that the season affects how high the tennis balls will bounce.

2. What made your choice the best?

What made the other statements not as good as the one you chose? Be specific about each statement.

APPENDIX F

ACTIVITY 2 – WRITING EXPLANATIONS FROM GIVEN SCENARIOS

ACTIVITY 2 – WRITING EXPLANATIONS FROM GIVEN SCENARIOS

Scenario 1:

A trebuchet is a device (like a teeter totter) used to launch obstacles into the air using a counter weight. In an experiment, students built a trebuchet with a 2 meter arm. They used a 7 kilogram counterweight to launch a baseball. They wanted to answer the question “how does position of the fulcrum affect the launch distance?”

Three trials were run and the following data recorded.

Distance of counterweight from fulcrum (meters)	Average distance of the ball launched (meters)
0.4 meter	5.2 meters
0.6 meter	4.2 meters
0.8meter	3.9 meters
1 meter	2.8 meters

Write a scientific explanation that addresses the question “does position of the fulcrum from the counter weight affect the distance a ball will launch?”

Scenario 2:

The military is doing an investigation to determine the effect of weight on a canon ball on the moon. A golf ball, a baseball and a bowling ball are all shot from the same canon under the same conditions in a vacuum chamber so that air resistance is eliminated. The following data were recorded.

Ball	Mass of ball (kilograms)	Distance (meters)
Golf ball	0.046 kg	27.5 m
Baseball	0.145 kg	27.5 m
Bowling ball	7.311 kg	27.5 m

Write a scientific explanation that addresses the question “how does weight of the canon ball affect the distance it will launch when air resistance is eliminated?”

Scenario 3:

Students at a science museum were given the materials to build a spool racer. (A spool racer uses a rubber band and a pencil to propel a spool along a flat surface. The pencil is used to twist the rubber band and is then set on the floor.) The students wanted to determine the effect of winding the spool racer different numbers of times on speed. The students determined speed by measuring the distance each racer went as well as its time in seconds. Three trials were conducted and the results averaged. The following data were recorded:

Number of turns	Speed (meters/second)
5	0.6 m/s
10	1.2 m/s
15	1.4 m/s
30	1.5 m/s

Write a scientific explanation that addresses the question “how does number of turns of the rubber band affect the speed of the spool racer?”

Scenario 4:

Sarah is entering a paper airplane design contest. Sarah thinks that adding paper clips to the nose of her airplane will make it go farther. She builds a paper airplane and then conducts an experiment by adding different numbers of paper clips and measuring how far it flies. She conducts three trials and averaged the results. The following table shows the data she recorded.

Number of paper clips	Distance (meters)
0	3.3 m
1	5.1 m
5	7.7 m
10	4.1 m

Write a scientific explanation that addresses the question “how does the number of paper clips added to the nose of a paper airplane affect the distance it flies?”

APPENDIX G

ACTIVITY 3 – WRITING A SCIENTIFIC EXPLANATION FROM STUDENT
COLLECTED DATA

ACTIVITY 3 – WRITING A SCIENTIFIC EXPLANATION FROM STUDENT
COLLECTED DATA

1. Students view a pendulum made from string (arm) and a washer (bob).
2. Students explore the period of a pendulum by varying its length, mass and amplitude.
3. Students will design and conduct an investigation to measure the effect of varying the mass of the bob of a pendulum, given that the length of the arm and the amplitude are maintained. The guiding question for the investigation will be “how does increasing the mass of the bob affect the period?” Students will collect data relating mass of the bob (independent variable) and period (dependent variable).
4. Students will write a scientific explanation for the data they collect in step 3. This explanation will be assessed using the same scoring rubric as the pre- and post-treatment assessment.