

THE 5E LEARNING CYCLE AND STUDENTS UNDERSTANDING OF THE
NATURE OF SCIENCE

by

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ABSTRACT

One of the most important aspects of teaching science is to provide students with the knowledge and tools for them to understand the nature of science (NOS). This project used a teaching technique called the 5E learning cycle. This learning cycle relies heavily on the teacher using inquiry in the classroom to support the students learning of NOS. The results indicated a marked improvement of student growth in NOS.

INTRODUCTION AND BACKGROUND

I am a science teacher in the rural town of Lingle, Wyoming. The town is located in south-eastern Wyoming and has a population of 520. The middle school and high school contain 179 students where I teach both sets of students. My schedule changes year to year depending on staff members and class numbers and I have taught all the major disciplines of science over the grades 6-12.

The Caucasian population at our school is overwhelming considering it comprises 94% of the entire student body grades 6-12. There are two African-American students and three Hispanic students in the entire school. More than half the students come from low-income families and are eligible for the free or reduced-price lunch program.

The scheduling of the classes at Lingle Ft. Laramie Schools consists of eight-50 minute periods for the middle school students and four-100 minute blocks for high school students. The days are designated as A days or B days for the high school so I see those students every-other day for their respective science class. The block system allows me to effectively take control of my classroom by integrating labs and lecture within one section of time. This is very important considering that the district, as well as the *National Science Education Standards* (1996), is now restructuring the teaching of science from that of memorization and decontextualized knowledge to that of inquiry.

Teaching through inquiry and the Nature of Science (NOS) is now considered the common theme of science education in our school district. After reviewing the scientific literature I chose the 5E Learning Cycle pedagogy as the focus of this study. The aspects that were targeted in NOS include hypothesis testing, the tentativeness of scientific

knowledge, the distinction between observational and inference, the creative and imaginative aspects of science, the definition of science, the subjectivity of scientific knowledge, the importance of empirical evidence, and the true meaning of a scientific theory.

After much deliberation I decided my focus question: To what extent does teaching through inquiry and the use of the 5E Learning Cycle affect student achievement of NOS mastery? Furthermore, as secondary questions: 1. I want to better understand how this intervention affects student attitude towards learning science? 2. Does the 5E learning cycle increase students overall grade in science class?

CONCEPTUAL FRAMEWORK

Effective learning is cultivated by effective teaching and cannot be left to chance (Pollard & Tann 1993). Learning science is wholly included within this statement. Times are changing from the recently obsolete behavioral theories, such as those of Skinner (1904-1990) and Thorndike (1894-1949) which were influential in primary education during the first half of the twentieth century, and placed the pupil in a comparatively passive role.

There is widespread agreement amongst science educators that students at all levels should be provided with opportunities in their science classes to reflect on and to develop more sophisticated understandings of the nature of science (NOS) (Driver, Leach, Millar, & Scott, 1996; Lederman & Neiss, 1997; McComas, Almazroa, & Clough, 1998; Abd-El-Khalick, 2005). Contemporary conceptions of NOS also reveal an

understanding of scientific knowledge as being testable and developmental and therefore subject to change, and knowledge of science as a human activity involving subjectivity, creativity and imagination in determining scientific knowledge. Those holding sophisticated conceptions of NOS would in addition reveal some understanding of how society and culture have affected scientific development in the past and how science and society are influenced and affected by one another in contemporary society (Lederman, 1998; Matthews, 1994; McComas et al., 1998). Such opportunities make sense of science and relate school science more closely to how science works (Murphy, 2010). Reform efforts in developing school science have also more recently focused on enabling students to develop sound conceptions of the NOS and scientific inquiry (American Association for the Advancement of Science (AAAS, 1990).

If pupils leave school with contemporary understandings of NOS, they could have a better understanding of science concepts and scientific inquiry, a greater interest in science and would have a better appreciation of science's role in contemporary society (McComas et al., 1998; Matthews, 1994; Lederman & Abd-El-Khalick, 1998). Such contemporary understandings and knowledge of science could lead to students finding science more interesting, comprehensible and relevant to their everyday lives (Murphy, 2010). McComas et al. (1998) Incorporating NOS as an integral part of a curriculum makes the students aware of the developmental NOS and humanizes the subject, making it more interesting for them to learn. Pupils who leave school with contemporary understandings of NOS have a better understanding of science concepts and scientific inquiry, a greater interest in science and have a better appreciation of sciences role in

contemporary society (McComas et al., 1998; Matthews, 1994; Lederman & Abd-El-Khalick, 1998).

NOS itself is an abstract idea and refers to the characteristics of scientific knowledge that necessarily result from the scientific investigations that scientist conduct to develop knowledge (Lederman & Abd-El-Khalick, 1998). Specific NOS topics should be incorporated into science instruction in order to promote a more scientifically literate society (Duschl, 1988; Ennis, 1979; Giddings, 1982; Lederman, 1983; Martin, 1972; Matthews, 1994; Robinson, 1968). Based on multiple overlapping science education standards documents, McComas, Almazroa and Clough (1998) created the following NOS objectives targeted for K-12 students: scientific knowledge while durable, has a tentative character; scientific knowledge relies heavily, but not entirely, on observation, experimental evidence, rational arguments, and skepticism; there is no one way to do science and therefore, there is no universal step-by-step scientific method; science is an attempt to explain natural phenomena; laws and theories serve different roles in science, therefore students would note that theories do not become laws even with additional evidence; people from all cultures contribute to science; new knowledge must be reported clearly and openly; scientists require accurate record keeping, peer review and replicability; observations are theory-laden; scientists are creative; the history of science reveals both an evolutionary and revolutionary character; science is part of social and cultural traditions; science and technology impact each other; and scientific ideas are affected by their social and historical milieu (McComas et al., 1998, p. 513).

Instructional strategies are more likely to be effective if they include inquiry (National Research Council [NRC], 2000), and inquiry-based learning supports the

conceptual understanding of science concepts (Lee & Krapfl, 2002) *The National Science Education Standards* (NRC, 1996) place more emphasis on inquiry, deemphasize the memorization of decontextualized knowledge, and encourage students to investigate the everyday world around them. The National Research Council (1996) indicated that a scientific understanding of targeted concepts can be promoted through inquiry when students actively participate in the learning. By conducting inquiry, students have firsthand experiences with the event, gather data, and analyze the data in an authentic way (Edelson, 2001). Inquiry skills include “formulating the hypothesis, collecting and evaluating evidence, and defending conclusion based evidence” (Edelson, 2001, p. 362). These skills seem to characterize the process of constructing scientific knowledge by the learner. Songer et al. (2002) noted that inquiry helps students to deepen their content understanding, develop problem-solving abilities, and gain ownership of knowledge.

An instructional tool called the 5E Learning Cycle is a systematic approach for teaching scientific inquiry in the classroom. The 5E Learning Cycle is seen as an effective hands-on, inquiry-based scientific pedagogy, especially for enhancing understanding (Bybee & Landes, 1988; Bybee et al., 2006; Stamp & O’Brian, 2005). This tool is one of the widely-adopted pedagogies as an indoor activity in the natural-science teaching (Bybee et al., 2006). In general, the 5E Learning Cycle is considered as a guided inquiry while the teacher provides only the materials and problems to investigate and students execute their own procedures to solve the problem under the guidance of teachers (Martin-Hauser, 2002; Windschitl, 2003).

The 5E Learning Cycle has been regarded as a general philosophy of teaching and learning with strong constructivist foundations. The 5E Learning Cycle consists of five

phases: engagement, exploration, explanation, elaboration, and evaluation (Bybee & Landes, 1988; Bybee et al., 2006; Eisenkraft, 2003). It is a teaching-and-learning procedure consistent with the privileged status of inquiry and with the ways in which students naturally learn (Musheno & Lawson, 1999). The following paragraphs include explanations of each phase of the 5E learning cycle (Bybee & Landes, 1988; Bybee et al., 2006; Stamp & O'Brian, 2005).

The following are the phases of the 5 E Learning Cycle Model (Bybee et al., 2006):

Engagement phase: The teacher assesses students' prior knowledge and engages students in learning a new concept. The teacher also helps make connections between prior and present knowledge, and helps to organize students' thoughts about the learning outcomes of present activities.

Exploration phase: The teacher provides students with a common base of activities reflective of present concepts, processes, and skills. Students complete activities by using prior knowledge to generate new ideas, to explore questions and possibilities, and to execute preliminary investigation.

Explanation phase: The teacher focuses students' attention on a specific aspect of their "engagement" and "exploration" experiences, and provides opportunities for students to demonstrate their understanding or skills. The teacher can also use direct instruction and guide the students toward a deeper understanding of a concept

Elaboration phase: The teacher challenges and extends students' conceptual understanding and skills. Students learn to develop broader and deeper understanding and skills, through the above three phases.

Evaluation phase: The teacher evaluates students' progress toward achieving the instructional goals. Students learn to assess their understanding and abilities.

METHODOLOGY

The purpose of this study is implement the 5E Learning Cycle into my science class and measure its effectiveness in terms of student achievement by their understanding of the Nature of Science (NOS). My project spanned two units of environmental science from early January to early March. I used four methods of gathering data. The methods were through student/teacher interviews, classroom lab grades, as well as student surveys.

The students that were tested were freshman. There are 15 students in this class. The class consists of eight boys and seven girls. All of these students are Caucasian and there is one student who is on an Individualized Education Program. They are usually very upbeat and for the most part always willing to complete the tasks that are asked of them. I have taught in this school for three years and have had this particular group of students every year in some capacity of science education. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

The first mode of gathering data was Student Interviews (Appendix A). These questions are intended to help me qualitatively understand how much the students know, or don't know, about the Nature of Science. They are open ended questions that allowed the students to express themselves clearly. The results were logged and compared with the results of the same interview after the intervention. This mode will serve strongly as baseline data to compare with the results of the same interview after the intervention of the 5E learning cycle.

The second data source was directly from the student's lab grade. The students are graded by the Lab Write-Up Rubric (Appendix B) that specifies many of the things that are demanded by the 5E discipline such as gathering data, graphing, drawing conclusions, etc. The total possible score for the lab is 32 points. This score is then taken as a percentage for reasons of simplification. For comparison purposes, the four labs that were completed previous to the implementation of the 5E learning cycle were averaged. This average grade was then compared to the averaged lab grades over the period of the intervention.

This school district has unit ending tests referred to as Common Assessments. This is a data gathering device by the school that is used by the district to measure student growth. To measure growth in NOS I will use two different District Common Assessments (Appendix C). The first common assessment was administered before treatment, as the second was given upon conclusion of the treatment.

The final mode of gathering data was that of Student Surveys (Appendix D). This also will be given pre and post treatment. To quantify the data, the Likert Scale will be

utilized to best evaluate student results. The Likert-Scale ranges from 1-5 (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree).

These four modes of data shown below in Table 1 should be sufficient to clearly determine how effective the 5E Learning Cycle is with a more defined injection of teaching science through inquiry affected the students overall understanding of the Nature of Science. These data sources described above are summarized in Table 1 below. They provide triangulated data for my focus and sub questions regarding the 5E learning cycle.

Table 1
Triangulation Matrix

Research questions	Data Source 1	Data Source 2	Data Source 3
1. Does the 5E learning cycle increase students overall understanding of NOS?	Student Survey	Student Interviews	Classroom Lab Write-Up Grade
2. How does using the 5E learning cycle affect student attitude towards learning science?	Student Survey	Student Interviews	
3. Does the 5E learning cycle increase students overall grade in science class?	Unit 3 Common Assessment Grade		Unit 4 Common Assessment Grade

DATA AND ANALYSIS

The results of the average grade comparison between Pre- and Post-5E indicated that grades either showed no gain or improvement per individual student (Figure 1,

$N=15$). An analysis of the depth of student questions indicated an increase throughout the project. Prior to the project, no questions were raised that indicated deep thinking about lab investigations, but after the project questions revealed a deeper understanding of investigations and the Nature of Science. One student asked, “So if I take all the variables and leave just one that I change, I can find out about anything, right?” Another said, “So you had instruments that measured close enough and eliminated variables, you could tell the future with a lot of stuff, huh?”

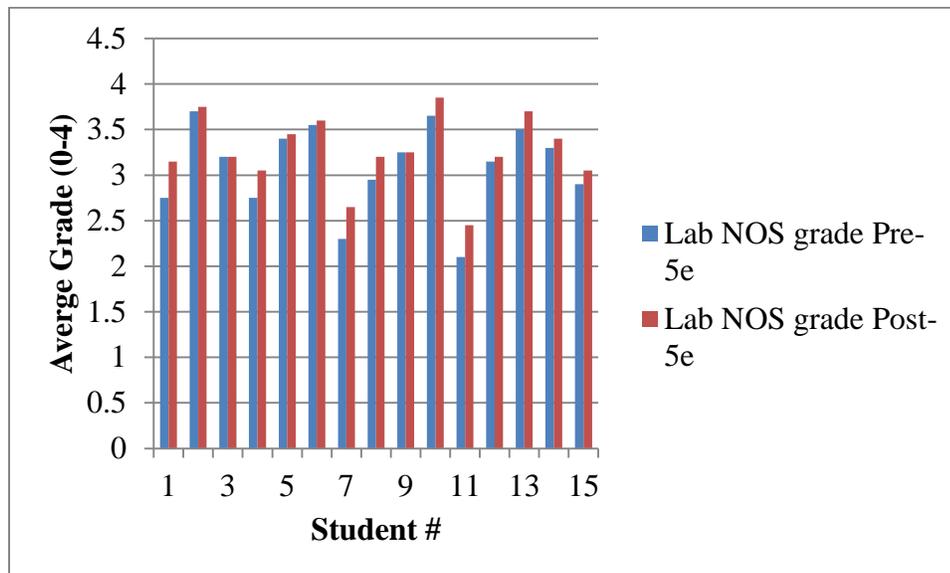


Figure 1. Pre and Post NOS Lab Grade, ($N=15$).

Interview responses followed the same trends (Appendix A). Prior to the 5E learning cycle, when asked how often they used NOS in their daily lives, most common answers were *nearly never to never*. One student responded, “Sometimes, when I am trying to prove my little brother wrong.” Another said, “Only when Mr. Cornelius makes us.” When the students were asked about their confidence in the use of the scientific method to complete a project, their common response was a simple *no*. After treatment

multiple students ($n=5$) simply answered *yes*. One student said, “You mean science fair right? If that is what you mean, it wasn’t that hard.” This response was from a student who placed 3rd in his category in the state science fair.

When the students were asked if learning science helps separate fact from fiction on a Likert Scale (1= Strongly disagree, 2= Disagree, 3= Neutral, 4= Agree, 5= Strongly agree) the results showed a rise of 0.4 from pre- to post-5E (Figure 2).

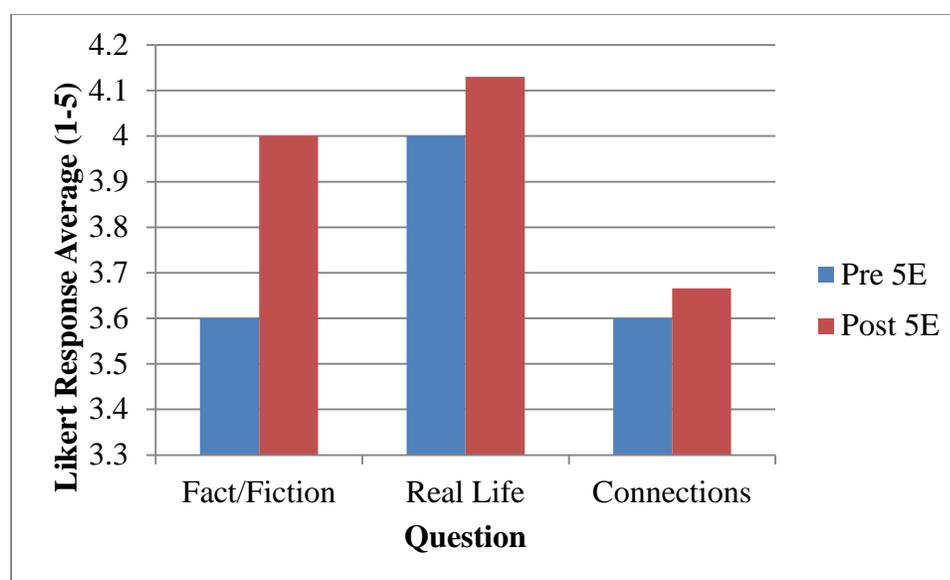


Figure 2. Pre and Post NOS Survey Responses, ($N=15$). Fact/Fiction= Learning science helps me separate fact from fiction, Real Life= The science in school will be useful for me in real life, Connections= I make connections between what I learn in science class with questions I may have in daily life.

When asked if the students enjoyed doing science the pre- and post-5E showed an increase of 0.266 points (Figure 3). There was also increase in student attitude when they were asked if they enjoyed coming to class (0.133 points).

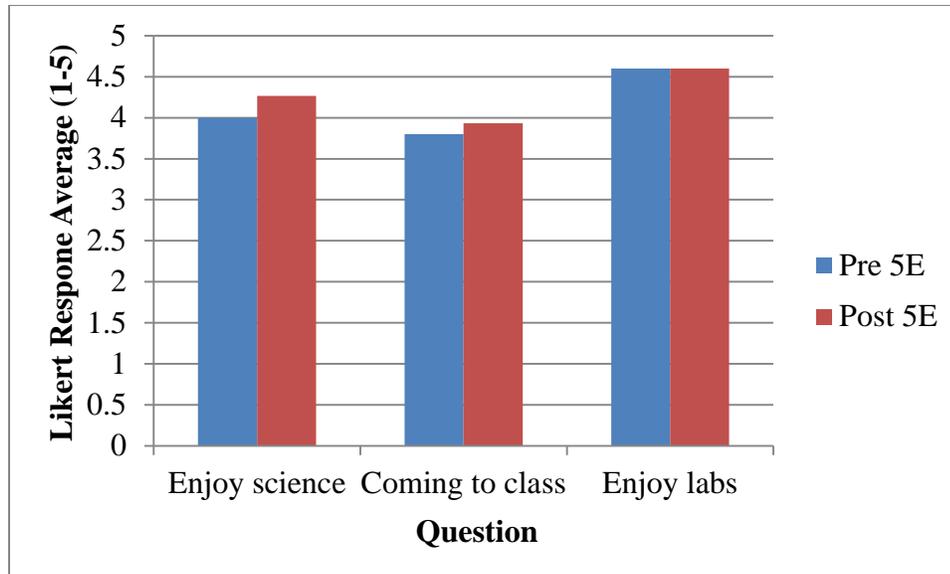


Figure 3. Pre and Post Attitude Response Averages, ($N=15$). Enjoy science= I enjoy doing science, Coming to class= I look forward to coming to class, Enjoy Labs= I enjoy doing the labs in this class.

When the students were asked if they enjoy doing science in the Student Interview (Appendix A) responses pre-5E indicative of the class were “It’s not really that bad.” Post 5E, a representative response of the class was, “I like coming to science class and finding out about something using my ideas, and not going by what a book is telling us.”

Two modes of data that were used to evaluate student grade showed marked increase in not only student lab grade, but also in student common assessment grade.

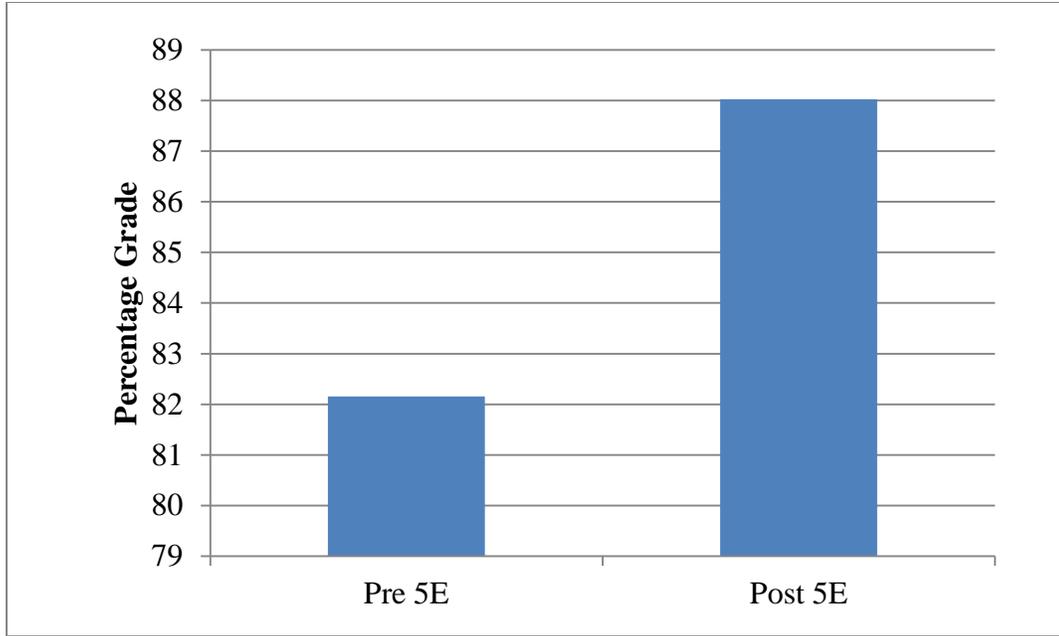


Figure 4. Pre and Post 5E Lab Grades, ($N=15$).

The student lab increased by 4.93%. Student reflections showed the same type of trend as responses to questions related to completing labs were representative of “Labs are cooler now.” and “My grade is way higher now than it was... after this thing.”

District assessment grades also moved in a positive fashion after treatment. The average class grade pre-5E showed to be 3.27 on a 4.0 point scale (Figure 5). The class average Pre-5E was 3.27 and after the 5 E the average grade point was .365, and increase of 11.1%.

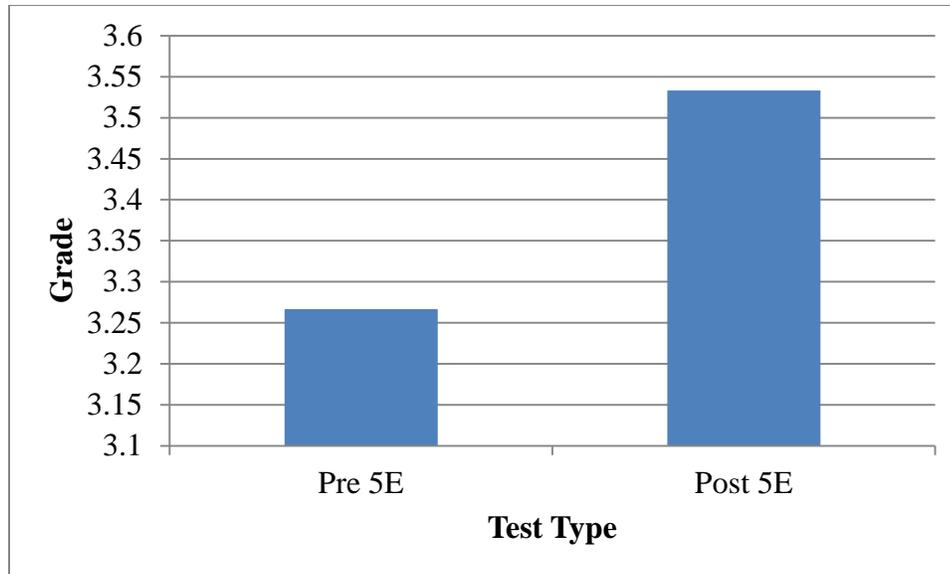


Figure 5. Pre and Post 5E District Assessment Grades, (N=15).

Post 5E data showed an increase in district assessment grade of 0.233. The scale for grading is a four point system that designates a word description to level of achievement. For example 1= Low, 2= Needs Work, 3= Proficient, 4= Mastery. There seemed to be a less ominous tone in class when there is to be a district assessment. Before treatment, class moral would drop to a low for the time of assessment. Comments heard at the introduction of the assessment were “sucky” and “These are worthless.” Upon completion of the project district assessments were not seen as such a negative activity as many students commented, “These are that bad anymore.”

INTERPRETATION AND CONCLUSION

This study provided evidence that the 5E learning cycle had a strong effect on students’ knowledge and use of the nature of science (NOS). Nearly every datum

represented a positive progression of student grades, as well as attitude towards NOS. A few months of the 5E learning cycle produced clear evidence of student growth in my science class.

When all three modes of data are looked at together, they show the same type of growth. This supports the conclusion that there was overall success with the implementation of the 5E learning cycle. This also is a very good indicator of validity, relevance and reliability. The modes of data that show the closest similar patterns are those of the common assessment and lab grade. When looked at together the data representation is nearly identical.

The results of the data also show that the students are very aware of their own learning. The survey responses of what they felt they learned were very representative when compared with that same student's lab grade and also classroom grade. This has led me to use surveys in my classroom that ask the student how successfully they feel they are learning.

Another very strong factor that has led me to believe this study was a large success, was the increase of score in the common assessment. This assessment tool was created solely to measure the students' understanding of the use of NOS. The creation of this tool was done by multiple science teachers and has been refined over many years. I feel strongly that these tests measure what they are intended to and the growth that this class exhibited over the short time of the project is a celebration. This study has shown many positive aspects of using the 5E learning cycle in my science class. The data speaks for itself and its role in helping students better understand and use NOS.

VALUE

This project has shown to have a profound effect on how students use the nature of science (NOS) in their daily life. The results have already shown to be far reaching in multiple disciplines as far as personal application, as well as improvement in students' science grades. Further implications may show to have an effect on ACT scores as well as PAWS results, the state mandated tests for Wyoming. Both tests focus their science sections on experimental design which is one of the aspects that was strongly covered in the 5E learning cycle. Students are able to make relevant connections and apply strategies and concepts from the learning cycle to improve themselves as science test takers.

Although I used the 5E learning cycle with this specific class, I also used partial aspects in other classes as I felt more comfortable implementing their use. Within the next year, I plan on continuing the learning cycle in all the classes I teach. The results will be thought-provoking and possibly the foundation has been laid for another extending research project.

Upon presentation of this project at the campus of Montana State University, and start-up of the next school year, there is a scheduled presentation of this project to the Goshen County School District Employees. This project presentation will be most applicable to the science in the department district. My hope is for this project to urge other professionals to delve into the world of class action research, considering how it has been vastly beneficial to my students as well as myself as teacher.

This project has had multiple positive influences on me as a person, as well as a professional. One very important lesson I have learned from this project is patience. This

project was done over a very tumultuous time in my life. Before this project I was not as patient with my students as I could have been. The project itself did not illicit this patience, it was the professors who have made concessions for me. Without their patience with me, I would never have completed this venture. It is their patience towards me that has helped me become a better teacher in this aspect with my own students.

Efficiency is another value that has come from this experience. In such a small school system, each teacher, as well as each student, is involved in multiple things at any given time. I am out of my classroom teaching for multiple reasons throughout the year. This also goes for the students who are absent for a multitude of reasons. This style of teaching science has made me more efficient so I can maximize the little time I have with the students. In the short time that I have used the 5E learning cycle I feel that I can make better use of my time with the students in turn allowing them learn at a higher level.

Furthermore, self-reflection from the onset of this project to completion has improved me as an inquiry teacher. Llewellyn (2007) has created a spectrum for inquiry teachers to follow as a stepping stone for teaching inquiry mastery. Initially I would confidently place myself in the first step, which is the foundation which entailed one to identify what goals a teacher would like to accomplish through teaching through inquiry. This project was not used only for my fulfillment of the MSSE program, but also as the professional development plan for my administrators in at my teaching assignment for the 2011-12 school year. Of the five steps Llewellyn identified, I would firmly place myself in step four which deals strongly with gaining new strategies and self-implementation of new ideas for improving teaching performance. The final step for me as an inquiry

teacher would be to find a support system for myself, which my administrator and myself hope to implement early next year.

I feel much more at ease using research-based instructional strategies. I am much more comfortable not only researching new tools, but also applying them in my classroom. This lesson is extremely valuable to me and I have helped teachers in other content areas find tools of their own that they are now using in their classrooms. This project has forced me to come out of my comfort zone and into the new territory of using educational literature in my profession.

This post graduate time has brought so many tools into my teaching repertoire. I have grown more as a teacher than I thought was even possible. I feel confident in my profession and have recently been moved into a lead teacher position in my district. I do not feel I would have this position without my post-graduate work. This project has taken my teaching to a level that I previously didn't realize existed.

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APPENDICES

APPENDIX A

STUDENT INTERVIEWS

Interview Questions

1. How often do you use NOS in your daily life? Explain.
2. Do you feel comfortable using your science knowledge to solve a problem using the scientific method? Explain.
3. Do you look forward to coming to science class? Explain.
4. What sort of lab activities do you find to be the most interesting? Explain.
5. Do you use what you learn in this class to help you solve scientific questions you many have?
6. When the science class is over do you feel relieved?
7. Does the information in class help you complete the lab activities at the end of each unit?
8. Are you proud of the work that you do in this class? Explain.
9. Do you feel confident enough to use your scientific knowledge to answer a scientific question and make a complete project to support your findings?

APPENDIX B

LAB WRITE-UP RUBRIC

Lab Report : Lab Write-Up

Teacher Name: **Mr. Cornelius**

Student Name: _____

CATEGORY	4	3	2	1
Question/Purpose	The purpose of the lab or the question to be answered during the lab is clearly identified and stated.	The purpose of the lab or the question to be answered during the lab is identified, but is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is partially identified, and is stated in a somewhat unclear manner.	The purpose of the lab or the question to be answered during the lab is erroneous or irrelevant.
Drawings/Diagrams	Clear, accurate diagrams are included and make the experiment easier to understand. Diagrams are labeled neatly and accurately.	Diagrams are included and are labeled neatly and accurately.	Diagrams are included and are labeled.	Needed diagrams are missing OR are missing important labels.
Procedures	Procedures are listed in clear steps. Each step is numbered and is a complete sentence.	Procedures are listed in a logical order, but steps are not numbered and/or are not in complete sentences.	Procedures are listed but are not in a logical order or are difficult to follow.	Procedures do not accurately list the steps of the experiment.
Calculations	All calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results are correct and labeled appropriately.	Some calculations are shown and the results labeled appropriately.	No calculations are shown OR results are inaccurate or mislabeled.

Scientific Concepts	Report illustrates an accurate and thorough understanding of scientific concepts underlying the lab.	Report illustrates an accurate understanding of most scientific concepts underlying the lab.	Report illustrates a limited understanding of scientific concepts underlying the lab.	Report illustrates inaccurate understanding of scientific concepts underlying the lab.
Experimental Design	Experimental design is a well-constructed test of the stated hypothesis.	Experimental design is adequate to test the hypothesis, but leaves some unanswered questions.	Experimental design is relevant to the hypothesis, but is not a complete test.	Experimental design is not relevant to the hypothesis.
Variables	All variables are clearly described with all relevant details.	All variables are clearly described with most relevant details.	Most variables are clearly described with most relevant details.	Variables are not described OR the majority lack sufficient detail.
Data	Professional looking and accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in tables and/or graphs. Graphs and tables are labeled and titled.	Accurate representation of the data in written form, but no graphs or tables are presented.	Data are not shown OR are inaccurate.

APPENDIX C

DISTRIC COMMON ASSESSMENTS

Environmental Science**Unit 4: Surface Processes Common Assessment Task EROSION PORTFOLIO**

Assessment task will be given at the beginning of Unit 4.

Students will have the entire length of the unit to work on assessment task

1. Take pictures of at least 10 landforms that are a result of erosion or deposition.

OR

Picture of 10 of the following landforms:

Yellowstone	Grand Canyon	Devil's Tower	Fossil Buttes
Vedauwoo	Laramie Mts.	Fremont Lake	Black Hills
Flaming Gorge	Absaroka Mts.	Wind River Canyon	Coal mines
Wild Cat Hills	Flint Beds	Toadstool Park	any other site in Wyoming

2. Pictures should be labeled with:
 - the type of erosion or deposition
 - where the pictures was taken
 - when the picture was taken
 - a brief description of what's happening
3. Pictures will be compiled into a portfolio that can be:
 - Poster
 - Power point
 - Word document
 - Anything else with teacher permission
4. Erosion Portfolio will be presented to the class and parents the last day of the unit.
5. Erosion Portfolio will be assessed using the following rubric

4 – Advanced	3- Proficient	2- Basic	1- Below Basic
Total of 15 or more items with labels, descriptions and explanations OR 10 items with latitude and longitude of each	- 10 items -Labels and descriptions -Explanation of what's happening	10 items - labels or descriptions or explanation OR 5-9 items with -labels, descriptions and explanations	10 items -NO labels or descriptions or explanations OR less than 5 items with -labels, descriptions and

OR			explanations
10 items with a map showing the location of each			

EcoColumn: Model Your Own Biosphere
(adapted from “Bottle Biology “EcoColumn)

The EcoColumn will be a model of the biosphere we live in. It will include the atmosphere, hydrosphere, and geosphere; and will demonstrate how the spheres interact. Your column will contain an aquatic, terrestrial and decomposition habitats; each will contain plants and may contain animals.

The plants and animals you stock your EcoColumn with will be determined by your group’s choice in variables.

What you stock your EcoColumn with involves your goals for study, the sources of your specimens — local or purchased — and your own creativity. Your EcoColumn will include producers, consumers, and decomposers. The simplest way to stock your EcoColumn is to collect from your local environment so that you can model the ecosystem in which you live.

Remember, there is no right or wrong way to build an EcoColumn. Change is a natural part of this experience, so when things change, try to figure out what happened and why. If insects or plants die in your EcoColumn, think again about the natural habitat of the living creature and what it might need to live.

Before Building your EcoColumn

With 1-2 partners, develop a building plan for your EcoColumn. Decide which of the following variables you will test in your EcoColumn:

- Type of soil: bring soil from home or use provided
- How many grass plugs: 1, 2 or 3 OR number of fast plant seeds: 1 – 5 fast plant seeds OR a combination of both
- How many animals: snails 1-5 OR guppies 1-3 OR Snail, guppy or both OR a combination of both
- What type of aquatic plant: elodea OR duckweed OR both
- What color bottle: green OR clear

Materials Needed For Building

- Three two-liter plastic bottles (bottle 1 provides a deep base and tops, bottles 2 and 3 provide deep funnel units)
- Three bottle caps (for top and deep funnel units)
- One 20-cm length of nylon craft cord (for wick)
- Permanent marker (for making marks)
- Utility knife (for starting bottle cuts)
- Drill (for making wick hole in bottle cap)
- Scissors (for finishing bottle cuts)

- Push pin (for making air holes)

General Building Instructions

Removing Labels and Bases:

- Remove labels from 3 two-liter bottles by heating the label with a hairdryer set on low. Hold you bottle about 10 cm away from the blowing nozzle, move the hairdryer by and down so that the air warms the seam of the label.
- Gently pull on an edge of the label until you feel the glue begin to give. *This takes about 4 seconds! Bottles will warp easily if overheated!* (bottle can be filled with water first to prevent warping)
- If the bottle has a colored base that needs to be removed; remove it by heating the base of the bottle for about 15 seconds or until you can twist the colored base off the bottle.

Cutting Bottles: The easiest way to cut a bottle is to cut along a marked line with scissors.

- To make the cutting line on the bottle brace the bottom of the bottle against a corner of a shallow box. Rest a marker against the edge of the box, so the tip rests against the bottle where you want your cutting line. Slowly turn the bottle. Two people make this job easy.
- After marking the cutting lines use a safety razor or utility knife to begin the bottle cuts. You only need a cut big enough to insert the top arm of a scissors.

Joining Bottles and Waterproof Joints

- Tape is the best material for joining bottles and will help columns survive handling in the classroom. Clear, waterproof tape about 5 cm wide works best. Fix the joint to be sealed with several small pieces of tape, which you can remove after the seal has solidified.
- To make a waterproof joint, use silicone sealant. Silicone sets over a 24-hour period if applied in a thin bead, 2-3 mm in diameter, is slippery when fresh, should be used in a well ventilated area.

Making Holes: for air and/or drainage

In bottle parts

- You will want holes small enough to keep fruit flies and other insets inside the decomposition section of your EcoColumn and not in the classroom.
- To have adequate ventilation for plants, insects and other life make four or five “stars” of holes - but keep the holes small by using a push pin or a safety pin.

In caps

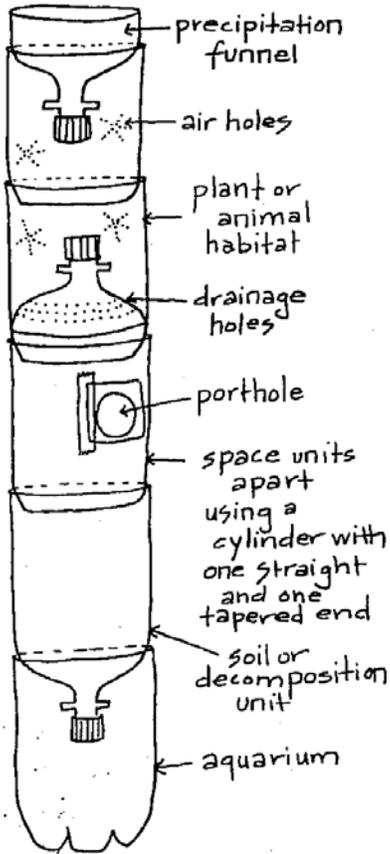
- Use a large needle that has been heated in a flame of a candle to melt a hole through the cap; or use a small drill bit to drill a hole in the cap.



bore or
punch holes
in caps to
interconnect
units → 

Building Your EcoColumn



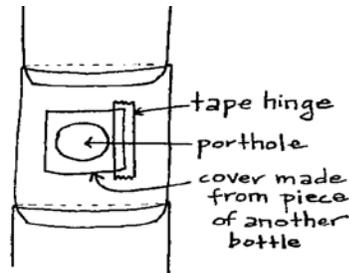


Cut the top off of two of the bottles about 1 cm below the shoulders. Cut the bottom off 1 cm below the hip.

Cut the top off of the third bottle about 1 cm below the shoulder.

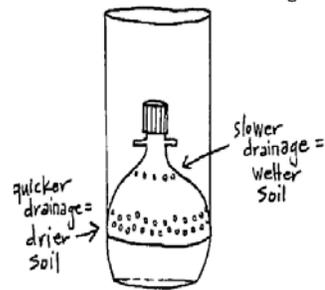


You now have stackable units – the tops, deep funnels (A) are either placed upside down or right side up into a cylinder (B). Part C becomes the base for your EcoColumn.



Make a porthole in one of the columns as shown ←

Make drainage holes in the deep funnels (A) for either slower or quicker drainage.



Before taping/sealing your pieces together stock the following habitats:

Materials Needed For Stocking and Maintaining

It's very important that all materials introduced into the EcoColumn — living, dead, or nonliving — are clean and free of anything that might be toxic to living things (e.g., oil, pesticides, etc.). The organisms you introduce should be small and suited to the habitats you construct. The number of organisms you introduce will depend on what they are, but it is better to add too few than too many, especially in the aquatic habitat. Bigger organisms should definitely be limited to one or two.

Aquatic Habitat Materials

- Fine grained aquarium gravel (provides “bedrock”)
- Sand or topsoil (provides bottom sediment)
- Untreated tap water or distilled water (provides aquatic habitat)
- “Boulders”, “sunken logs,” and other miniature objects typical of a pond bottom
- Aquatic plants and animals
- Fish food (if you include a fish)

Aquatic Habitat Stocking Instructions (this will be the bottom section or aquarium)

1. Add a layer of sand or topsoil (2-3 cm) to the base section (C).
2. Add a layer of gravel (1-2 cm) on top of the sand or topsoil
3. Add water to a level about 1 cm below the cap of the lower funnel (A).
4. Plant aquatic plants with roots (elodea) in the bottom of the sediment.
5. Arrange “boulders” and other objects on the bottom sediment.
6. Add floating aquatic plants (duckweed).
7. Let your aquarium sit until the sediment settles.
8. Add aquatic animals.

Compost Habitat Building Materials

- Fine grained aquarium gravel (provides “bedrock”)
- Sand/topsoil mix (provides soil substrate)
- Leaf litter or grass clippings (provides compost habitat)
- A few chunks of turnips, potato, apple or other roots, stems or fruits)
- Earthworms, pill bugs, millipedes, and other natural inhabitants of leaf litter

Compost Habitat Stocking Instructions

1. Add a 1-2 cm layer of gravel to a deep funnel.
2. Mix equal parts of sand and topsoil together and add a layer (2-3 cm) over the gravel.
3. Add leaf litter and/or grass clippings to about 1 cm below the cap of the upper deep funnel.
4. Mix food items in, moving them to the sides of the habitat for better observations.
5. Add compost animals as needed (you will probably collect some with the leaf litter).
6. Establish a “water connection” between the aquatic and compost habitats by slowly pouring water down the side of the compost until it drips from the bottle cap into the aquarium.

Terrestrial Habitat Building Materials

- Fine-grained aquarium gravel (provides “bedrock”)
- Topsoil (provides soil substrate)
- Leaf litter (provides decaying material)
- Terrestrial plants and animals
- Food for animals as needed
- Optional: “boulders,” dead trees,” and other miniature objects typical of a forest habitat

Terrestrial Habitat Stocking Instructions

1. Add a layer (1-2 cm) of gravel to a deep funnel (A)
2. Mix equal parts of leaf litter and topsoil together, moisten, and add a layer (6-8 cm) over the gravel.
3. Add terrestrial animals that burrow (earthworms) to the soil.
4. Plant terrestrial plants (grass plugs) or seeds (fast plants) in the soil.
5. Add “optional” materials onto the soil if included in your plan.
6. Add “optional additional terrestrial animals if included in your plan.

Maintenance Instructions

1. EcoColumns become top-heavy and tips easily. Handle carefully while maintaining.
2. Provide a light source, preferable indirect window light. A small desk lamp or plant light will work, too. For artificial lights, provide 12-14 hours of light daily.
3. Add a small amount of water to the terrestrial habitat weekly or when it appears to be drying out. A fine spray of water on the plants also maintains the unit well.
4. Regularly feed plants and/or animals that require an external food source.

Observations: In your own words

- Keep a careful notebook as you plan your EcoColumn and record exactly what you put inside. Once you have set up a column keep careful watch on how conditions change. Describe changes in your notebook.

Common Assessment Task

Biosphere Interactions: Explanation of how the atmosphere, hydrosphere and geosphere interact within the biosphere and group model of biosphere.

The Earth is a closed system, in which nothing moves in or out. If you place a cap on top of your EcoColumn and don't poke any holes in the very bottom, have you created a closed system? (Not completely, of course, since air and water vapor will circulate through the air holes, and light enters through the bottles; but your EcoColumn becomes model of Earth's biosphere!)

Compare your EcoColumn as a closed system to our situation on Earth. Within its surrounding atmosphere, Earth is a largely closed system. That is water, minerals, and elements such as carbon and nitrogen move in great cycles, constantly exchanging between air, earth, water, plants and animals.

- Explain how temperature changes in the atmosphere affect the biosphere.

- Explain how water cycles in the biosphere and is modeled in your EcoColumn
- Explain how landforms and soil type affect the biosphere.

Biosphere Interactions: Explanation of how the atmosphere, hydrosphere and geosphere interact within the biosphere and group model of biosphere.

	4	3	2	1
content	Includes all the components of a “3” AND carbon-oxygen cycle OR nitrogen cycle and	Demonstrates thorough understanding of biosphere by explaining interactions between atmosphere, hydrosphere and geosphere including water cycle, weathering and erosion.	Missing one or more components of a “3’	Cycle is incomplete
	Includes all the components of a “3” AND Weather components OR Current examples	Applies earlier learning to a new context by comparing given examples to group biosphere. <ul style="list-style-type: none"> • Atmospheric composition • Water cycle • Effects of weathering and erosion 	Missing one or more components of a “3”	Response is incomplete
Writing	Writer expresses and communicates clearly, using scientific terms correctly and appropriately, economically, and at a level which can be understood by whomever reads the explanation AND the explanation expands the readers knowledge	Writer expresses and communicates clearly, using scientific terms correctly and appropriately, and at a level which can be understood by whomever reads the explanation.	Writer makes errors in grammar or spelling that distracts the reader from the content or results in unclear explanation.	Writer makes errors in grammar or spelling that make document difficult to read and understand.

APPENDIX D

STUDENT SURVEYS

Please rank your answer from 1 to 5. Write the number at the end of each statement. The number codes to the following responses:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Questions:

1. I enjoy doing science.
2. Learning science helps me separate fact from fiction in everyday life.
3. I look forward to coming to science class.
4. The teacher provides an environment that is comfortable enough for me to ask any type of scientific question.
5. The science in school will be useful for me in real life.
6. I make connections between what I learn in science class with questions I may have in my daily life.
7. I talk a lot about my science class with my family.
8. I enjoy doing the labs in this class.
9. I feel that the labs that I do in this class have a clear relationship with.