

EARTH SCIENCE AND BIOLOGY CONNECTIONS: ENHANCING EARTH SCIENCE
RELEVANCE FOR STUDENTS THROUGH BIOLOGICAL EXPLORATIONS

By

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ABSTRACT

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Earth Science is regularly marginalized as a high school science subject, ironically at a time when its significance might never have been higher. While this marginalization may occur in a variety of ways among the stakeholders involved in Earth Science education, among students it is often discernible as an apparent lack of interest in the subject material. Students frequently express that the relevance of the course is not obvious for them, and as such deem Earth Science as having little to offer them in terms of practical and applicable scientific knowledge. This is often in contrast with the relevance purported to exist by students when reflecting on their experiences within Biology.

A series of Earth Science activities with biological implications were implemented to determine if relevance of the topics could be conveyed to students when coupled with their prior experiences and knowledge of Biology. The Earth Science topics covered represented subject matter from each of the 4 spheres of Earth Science (geosphere, atmosphere, hydrosphere, as well as the biosphere). The activities included a range of science processing skills, including modeling, experimentation, measuring and collecting data, as well as reading scientific literature.

Students expressed a greater sense of relevancy in regard to Earth Science at the culmination of the study; both through direct expression via survey as well as through traditional assessment of course content knowledge. Additionally, students communicated a significantly increased appreciation for both nature and the connections between Biology and Earth Science.

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Introduction

Rationale:

Making science relevant for students is often regarded as a cornerstone to ensuring student interest in the subject matter, as well as promoting life-long science literacy, critical thinking, and valuable science processing skills. Students often sort the knowledge they are presented with as either applicable to their lives, or irrelevant and thus of lesser importance. Among the sciences, secondary students typically perceive the direct relevance of Biology in their lives whether through physiological and medical applications or through the biological aspects of agriculture. The relevance of Earth Science, as perceived by High School students, may not be as apparent. This perception is notably misinformed, as Earth Science affects questions of their future, such as “Where is our energy going to come from?” as well as questions of today, “Will we have a game today, or is the weather changing to become stormy?”. With further investigation, secondary students are likely to discover that Earth Science is as much relevant to them as Biology, and in many cases it’s relevant in conjunction with biological concepts with which they are already familiar.

Central to this study is the question of whether Earth Science relevance can be increased for secondary students through connections shared with Biology. Since students recognize Biology as having relevance in their lives, both now and in the future, it appears that Earth Science should convey to these students a similar level of significance when presented and explored in conjunction with associated biological concepts. Of further interest is the thought that there are concepts in Biology germane to each of the Earth Science standards to be mastered by the students, biological concepts with which they are familiar and have already deemed relevant. The underlying premise then becomes a matter of taking what students have

experienced, shown interest in, and presumably been successful at, and build from it as their scientific attention is turned from the biological to the geological, hydrological, and atmospheric world.

Further aspects of promoting relevancy were also considered, such as making the learning process authentic, relating the topics to contemporary issues, and demonstrating the connections to their community. Additionally, associated activities were incorporated that would enhance the opportunity to impart science processing skills to students. These skills ranged from graphing and illustrating, to measuring, recording, and organizing data.

Through implementing the activities, the desired outcomes of greater student interest, an increase in understanding of the resources provided by the Earth, and an awareness of contemporary issues concerning Earth Science were sought. Each activity was executed to ensure student application of science process skills, and highlight the connections existing in nature common to both Earth Science and Biology. Further, where possible, the activities were conducted outdoors to increase student exposure to nature and increase the opportunity for experiencing Earth Science in its preeminent laboratory setting, the outside world. Covering a wide spectrum of Earth Science topics, the activities and assessments were convened over the span of the two semester course, encompassing the concepts of insolation, carbon and nitrogen cycling, soil types, volcanoes, the magnetic field, the hydrological cycle, as well as aquifers and water quality.

This series of activities was assembled during the summer research period of 2010, with modifications and implementation of the lessons occurring during the 2010-2011 school year. Students were presented with Ann Arbor Public School's Earth Science curriculum, but where applicable activities related to biology were interjected to enhance the topics being taught.

In conjunction with the activities, and in addition to the curriculum mandated assessments, students were assessed through pre and post test. Each test pair consisted of five questions of interest to the topic being studied. Data from the pre and post test were then statistically compared to determine the effectiveness of the activity in conveying Earth Science content and relevance to the students in light of their prior knowledge of Biology. Students were also requested to participate in a culminating survey, the purpose of which was to elicit student opinion in regard to course relevance.

Through incorporating hands-on activities, which access prior scientific knowledge from a subject area deemed relevant, it is expected that students will find Earth Science relevant as indicated by pre and post test measurement. It is further predicted that students will express an increased sentiment of relevance through the informal survey.

Theoretical Framework:

The importance of Earth Science for today's high school students should not be undervalued. With increasing occurrences of severe weather events, documented shifts in climate change, and an ever-rising need for natural resources due to our growing population, present-day secondary students need Earth Science in order to be scientifically literate and to fully develop an understanding of the environmental and resource challenges they will experience in the course of their lives (Geological Society of America, 2005). While other science disciplines within secondary education also impart scientific literacy, only Earth Science does so in a manner that addresses how our demand of natural resources affects the planet, and provides for an understanding of Earth's systems and how to properly manage the resources we obtain (American Geological Institute, 2004).

Paradoxical however, is the reality that Earth Science education does not always receive the consideration it merits. Historically in American secondary education, the Earth Sciences have typically been established as electives, with Physics and Chemistry viewed as providing greater opportunities for student engagement in problem solving and practical scientific knowledge (Dodick, 2003). Students and parents are likely to regard the Earth Sciences as marginal, in favor of Biology, Chemistry, Physics, and AP courses (Metz, 2008). Earth Science is less likely to be taught by qualified instructors when contrasted with other science disciplines, and as such may not benefit from the advocacy of professionals vested in the subject matter (Wiess, 2002). Change in regard to the perception of Earth Science is impending though, as states are increasingly adopting the subject within their curriculums and professional organizations are encouraging an increased presence of the Earth Sciences within secondary science programs (Benbow, 2007).

If Earth Science is important to secondary science education, then it is equally imperative to identify what content should be taught to high school students. Earth Science educators are only beginning to identify the scope and sequence of the discipline, as well as seeking to unify the subtopics of geology, meteorology, astronomy, and hydrology (Finley, 2011). Many science educators and Earth Science professionals have sought to incorporate an understanding that each of the science disciplines are connected to our planet. Each of the science disciplines can contribute to a better understanding of the Earth systems presiding over our existence (Mayer, 1990). Earth Science, perhaps more so than other facets of secondary science curriculum, has great potential for providing an example to high school students of the interdisciplinary nature of modern, practical science (Metz, 2005).

As with other secondary science disciplines, Earth Science must communicate to high school students its relevance. Imparting relevance of the subject matter to secondary students is demonstrated to elevate student interest and environmental literacy, increases their awareness of local resource issues, and enhances their enjoyment of hands-on science activity (Eick, 2008). Making science relevant through integrating various disciplines within the curriculum has been identified as a means through which students develop integrative academic connections their life experiences alone are not yet able to endow (Klemm, 2008). Promoting science relevancy can be difficult however, as students may connect with the subject matter in many disparate ways, such as historically, socially, and conceptually (Sterling, 2009). In addressing the concern of relevancy having variable interpretations among a student population, this study seeks to provide as many avenues to relevant science as possible within each lesson.

Earth Science addresses natural phenomena that typically occur outside of the classroom setting, and as such its relevancy may be encouraged when experienced outdoors. Practicing and learning Earth Science in an outdoor setting allows for the connection of content to the environment and nature, and permits the school's surroundings to serve as an inquiry-based laboratory (Tatarchuk, 2011). The outdoors may yield for a science teacher a setting in which students can abundantly exercise science-process skills, including observation, prediction, and classifying, as well as literacy skills, such as summarizing, sequencing, and drawing conclusions (Ibid). In searching for venues for outdoor Earth Science education, an assortment of possible choices exists, ranging from school grounds and nearby parks to local college campuses and natural history museums (Benbow, 2008). Beyond the concepts divulged through Earth Science in an outside setting, providing students with experiences in the outdoors can also impart a renewed sense of wonder in nature, thus enhancing science relevance, and often nurtures creativity in students both within and separate from the sciences (Louv, 2005). In the objective of generating relevance through settings beyond the classroom, locations in addition to the outdoors may also be appropriate, including in their own homes where products produced through resources obtained through Earth Science knowledge may be found (Liftig, 2008).

A number of science activities have been developed which demonstrate specific connections between Earth Science and Biology, and lend themselves to adaptation within Earth Science courses. The most prominent is the illustration of closed systems presented by Earth Systems in a Bottle. Many aspects of science, including chemistry and physics, are often incorporated into Earth Science activities, and serve to advance students' science experiences beyond the geological, and illustrate for students that science, in practical terms, is exceedingly multidisciplinary (Henriques, 2000). Activities centered on ecosystems regularly highlight the

interactions that occur across the geosphere, biosphere, hydrosphere, and atmosphere, and may be used to engage students in Earth Science through the enthusiasm they frequently express for biology labs. These activities are readily adaptable for addressing specific questions on interactions between systems, or for collecting data to answer inquiries in regard to a single system within the complex (Rutherford, 2004).

Through exploration of activities that bring together Earth Science and Biology, students gain the opportunity to observe interactions between what might seem to them as disparate science facts and concepts (Mayer, 1995). Exposure to cross-disciplinary activities not only enhances students' enjoyment of the science being explored, but promotes Earth Science literacy for contemporary secondary students when presented within an integrated science curriculum (Ibid). As school districts seek science programs that integrate science topics, provide for the use of technology, interject the use of alternative assessments, and place emphasis on inquiry-based science exploration by students, numerous teachers have turned toward course development that employs lessons asserting connections between Earth Science and Biology. Through biological connections to Earth Science, these activities have demonstrated reinforcement of the intricate and interconnected nature of science, and a focus on the science process skills present in the traditional science curriculum sequence of Biology, Chemistry, and Physics. Engaging students in biologically related Earth Science lessons can elicit from them a greater interest in, and passion about, the study of science and the Earth's environment (Everett, 2008).

Relevance in science for students may be elicited in a variety of ways beyond connecting with a previously studied subject area. Students may also find relevance in Earth Science through such factors as guided inquiry based studies, open inquiry investigations, local experiences, issues-based explorations, practicing science process skills, or opportunities for

cooperative learning with classmates. Incorporating the methods employed by professional Earth Scientists can enrich the understanding of the material for high school students. It also allows students to discern how the process of discovery used by scientist can lead to the concepts they are learning (Kastens, 2008). By providing situations for students to take ownership of their educational outcomes, open-inquiry can furnish students the situation in which to determine scientific questions and experimental procedures, and ascertain their own conclusions (Hermann, 2010). Local experiences can also impart a sense of relevance to students, yielding occasions in which they can become aware that science occurs around them. Integrating science with local experiences increases student appreciation and acknowledgement of science as an integral part of everyday life (Black, 2004). Framing science instruction around contemporary issues may further the sentiment that science has relevance in students' lives. Such an approach to issues-based science can be enhanced when the instruction seeks to discuss the science in the context of personal or societal issues, consists of collaboration with small groups, provides for application of conceptual knowledge, requires the use of evidence, and is evaluated through authentic assessments (Wilmes, 2009).

Cooperative learning has been shown to increase students' performance in regard to scientific application (Chang, 1999). Hands on science opportunities, putting into practice science process skills, may also enhance relevance for high school students. Through utilizing and developing science process skills, particularly those which are acquisitive, organizational, creative, manipulative, and communicative, students are known to express a feeling of accomplishment and satisfaction with their science education experiences (DeFina, 2006). Providing secondary students with a relevant Earth Science experience may also require the incorporation of an inquiry teaching method. The application of inquiry teaching methods can

lead to not only greater academic achievement by students, but also to the development of more positive attitudes toward Earth Science among middle and high school pupils (Mao, 1998).

In seeking to measure student achievement, conceptual understanding, and sense of relevance an appropriate assessment instrument must be employed. Dr. Victor Mayer (1982), of Ohio State University, provides an overview of the possible choices for such an assessment instrument, and indicates that a wide variety of assessment instruments and techniques may be appropriate for determining both students' academic achievement and attitudes regarding science. His assessment instruments featured respondent completed forms for which a single score could be generated for each characteristic of interest.

Making any science course, Earth Science or otherwise, relevant to contemporary secondary students would certainly appear to be a formidable task for an educator. As indicated by Douglas Newton in his work, Making Science Education Relevant (1982), science education can be made relevant when it is humanized, fulfils needs, provides a model for investigation of the natural world, and offers a vehicle through which a holistic world view can be developed. While science may be taught that is remote from most people's lives, particularly through presentation of science as a set of isolated facts and skills, it may also be delivered through methods which connect science with that which students perceive to have importance and value. An integrated approach to the sciences may further enhance relevance for high school students when the course seeks to address current topical issues, authentic opportunities to investigate, and occasions for student collaboration on class projects.

An Overview of the Science

Earth Science encompasses a great variety of topics and concepts. During the year-long course reported in this study, students explored the 4 systems of Earth Science: the geosphere, the atmosphere, the hydrosphere, and the biosphere, as well as the universe beyond our planet's environs. Of particular celestial interest within the solar system, and studied early within our course, is the Sun, the primary provider of energy driving Earth's systems. As outlined in Table 1, the four Earth systems were studied throughout the school year with the geosphere, hydrosphere, and atmosphere being generally confined to academic quarters two, three, and four respectively. The first quarter consist primarily with the study of the universe, the Sun and its cycles, as well as an overview of chemistry and introduction to minerals.

Table 1. Ann Arbor Public Schools Earth Science Curriculum for 2010-2011

(Chapters from *Holt Earth Science*, 2007)

	1st Marking Period	2nd Marking Period	3rd Marking Period	4th Marking Period
Week 1	Intro to Earth Science	CH 4 Chemistry	CH 11 The Crust	CH 19 Oceans
Week 2	CH 1 Science	CH 5 Minerals	CH 12 Earthquakes	CH 20 Ocean Water
Week 3	CH 2 Earth Systems	CH 6 Rocks	CH 13 Volcanoes	CH 21 Waves
Week 4	CH 26 Space	CH 7 Resources	CH 14 Weathering	CH 22 Atmosphere
Week 5	CH 27 Planets	CH 8 Rock Record	CH 15 Rivers	CH 23 Precipitation
Week 6	CH 28 Solar System	CH 9 Earth's Past	CH 16 Groundwater	CH 24 Weather
Week 7	CH 29 The Sun	CH 10 Tectonics	CH 17 Glaciers	CH 25 Climate
Week 8	CH 30 Stars / Galaxies	Recovery & Review	CH 18 Erosion	Recovery & Review
Week 9	CH 3 Earth Models	Finals	MME Week	Finals

While the traditional focus within the course has generally been on the geosphere, hydrosphere, and atmosphere, it was sought to increasingly integrate the interactions of those three Earth systems with the biosphere. This was intended to primarily serve the purpose of generating student relevance for the first three systems, but may also provide reinforcement for the previous year's biological studies. Like the diverse spectrum of topics covered by the course, the activities performed by the students over the span of the study were equally varied.

Within the first quarter, and relevant to the study, students explored the concepts of open and closed systems, the Sun and its function as Earth's primary energy source, the carbon and nitrogen cycles, and Earth's magnetic field.

Students were expected to be able to differentiate between open and closed systems, as well as to discern that the Earth is a closed system in regard to exchanges of matter. In defining closed systems, these are systems in which matter is not externally exchanged, introduced, or reduced. Open systems in contrast do readily exchange materials with their surroundings.

Study of the Sun provided students with the opportunity to discover its cyclic sunspot behavior and its role as a primary source of energy for the Earth. Of rising interest is the Sun's solar cycle, as solar flares from cyclic peaks often interact with or disrupt satellites and the communications they provide.

The carbon cycle illustrated for students the concept of chemical reservoirs within the Earth systems and how an element may exist in a variety of compounds as it is transferred between the systems. The students were to distinguish between beneficial forms of the element and instances when the element may present harm through acting as a pollutant. Through its

presence in the atmosphere, as carbon dioxide, and then within plants as glucose, the carbon cycle exhibits for students the chemical connections between Biology and Earth Science.

Likewise the nitrogen cycle illustrated further chemical interactions among Earth systems and Biology, particularly through our use of fertilizers within industrialized agriculture and runoff which may pose problems within the hydrosphere, such as the dead zone in the Gulf of Mexico or algal blooms within our Great Lakes.

Expanding on the connections between Earth's systems and the biological world, students studied the Earth's magnetic field in concurrence with learning about various models and maps of the Earth. The Earth's magnetic field has long been used by human beings to navigate around the globe, but modern investigations point toward other species having an innate ability to use this field as a navigational tool as well. While studies into this interaction are being conducted, particularly in regard to avian and insect species, little is yet known about how other members of the animal kingdom use the magnetic field to find their way during migrations.

While the first quarter focused on introducing Earth's systems and highlighting the aforementioned aspects, the second quarter took a look into Earth's history through the use of carbon dating and index fossils.

Earth's history spans an approximate 4.6 billion years, a duration of time not easily fathomed by secondary students. While perhaps familiar with human history, it was less likely that students were as familiar with Earth's historic events such as its formation, the development of its oxygen containing atmosphere, the introduction of life, or extinction and ice age events after its inhabitation.

Index fossils provide one example of a biological connection to Earth's rock record. They are fossils that may be used to identify the geological period in which a particular sedimentary layer was formed, provided they exhibit the characteristics of originating from a short time span, uniquely identifiable, and broadly distributed. Connecting the fossils with the eras in which they were present provides geologist with an additional tool by which they may determine a geological record for a particular series of strata.

Carbon dating, a form of radiometric dating, may also be used to determine the ages of sedimentary rock layers through determination of the age of fossils contained within it. Living things uptake carbon, plants through respiration and animals through consuming plants or other animals. A portion of this carbon is C^{14} , which undergoes radioactive decay at a fixed exponential rate, allows the age of the organism, and the sedimentary layer in which it was encased, to be determined.

During the 3rd portion of the year the course ambitiously engaged in the more traditional Earth Science topics of Geology and Hydrology, notably covering volcanoes, soil types, wetlands, rivers, lakes, and aquifers.

Volcanoes display a very punctuated instance of geological change, and bring with their eruptions nearly unmatched biological upheaval. This disruption yields opportunities for biologists to study ecosystems' ability to rebound, and the aftereffects of such a significant occurrence on natural selection. As a recent North American volcanic eruption, Mt. St. Helens and the rebound of its surroundings is of considerable investigative interest. A stratovolcano located in the United States Pacific Northwest region, within the state of Washington, Mt. St.

Helens is one of 160 volcanoes comprising the Pacific ring of fire. Its May 18th, 1980 eruption left behind substantial ecological devastation, and biologists have actively sought to study the biological and environmental change occurring during the past 30 years since. This geological event may provide momentous insight into evolution and reforestation, as indicated by the May 2010 article, Mountain Transformed (Funk, 2010).

Less stark, and by far more ordinary, is the formation of soils and the biological connection soils invoke through agriculture and the plant kingdom. Soils typically bring to mind for students their mineral composition, but contained within them are also organic and biological components of tremendous importance. Formed from weathered rock, and often moved by facets of the hydrosphere and biosphere, soils provide sites of anchorage for plants as well as the mineral content required for their growth and development. Investigating both the mineral and biological composition of various soil mixtures, students were to discern which soil would be best for a hypothetical crop of soy beans, a valuable plant in Michigan's agricultural economy.

Just as Michigan's agricultural economy depends on its soil, so too does its agricultural industry and citizenry depend upon its freshwater resources. Highlighting Michigan's lakes, rivers, and streams as habitats for both plants and animals, particularly fish, the students took time away from the more traditional study of the geosphere and hydrosphere to learn about the inhabitants that can be found around our local surface waters. For lakes and rivers, students employed both Dave Bosanko's Fish of Michigan Field Guide, as well as Wetland Plants of Michigan by Steve Chadde, to explore and discover the variety of life which may be found within our surface waters and wetland habitats. Trees, also of biological significance in our state, was of further interest to students as the classes sought to discern a relationship between distances to surface waters and the species of trees which were present.

Aquifers, of vital importance to Michigan's communities as sources of municipal water, were also investigated during this period. Students utilized science process skills, particularly modeling and measuring, to research the concepts of inputs, outputs, recharge, and discharge as related to groundwater. Students were expected to discern between input/output and discharge/recharge, wherein inputs and outputs depict water being contributed or withdrawn from the aquifer without regard to the state of water volume within it while discharge and recharge refer to conditions in which the volume of water within the aquifer is undergoing measurable change due to the differences between input and output rates.

The 4th Quarter transitioned to observing the weather and our climate, and exploring the hydrologic cycle and greenhouse gasses respectively.

The hydrologic cycle, better known to students as the water cycle, consists of the transfer of water between Earth's various systems through physical processes. Those processes include evaporation, condensation, sublimation, freezing, melting, and precipitation. Additionally, connecting the hydrologic cycle to the biosphere, is the process of transpiration. Plants transpire water into the atmosphere through their stomata, which are pores that regulate gas exchanges. Students investigated this phenomenon by comparing the amount of water that could be collected from various species of trees located within the school's campus.

Greenhouse gases are of increasing climatological interest for their role in global warming. Among the various greenhouse gases are water vapor, nitrous oxide, methane, ozone, and carbon dioxide. Carbon dioxide's implications as a greenhouse gas have been correlated with its escalating concentration in the atmosphere as a result of industrial and automotive

combustion. Students were expected to analyze the empirical relationship between atmospheric carbon dioxide levels and the average global temperature for the past 150 years.

Students were also expected to be able to explain how climatologists can use oxygen isotopes trapped within ice cores to determine paleotemperatures. From this information students were then asked to make predictions regarding future global temperatures.

Demographics:

Conducted at Huron High School in Ann Arbor, Michigan, this study consisted of 10th grade students enrolled in the course Earth Science. Ann Arbor is located in southeastern Michigan, within the county of Washtenaw. The city is home to the University of Michigan, a public research university which, along with its Health System, composes the largest employer of county residents. The city, which is the sixth largest in the state, reported a 2010 census population of 113,943 in conjunction with a metropolitan statistical area population of 344,791.

The Ann Arbor Public Schools provided K through 12 educational services to 16,400 students from the City of Ann Arbor, as well as the portions of the eight bordering townships. The district encompassed an area of 125 square miles, and consists of 20 elementary schools, 5 middle schools, 3 comprehensive high schools, and 3 alternative high schools. For the 2010-2011 school year, the per pupil allocation within the district was \$9,336.

Huron High School, one of the three comprehensive high schools, consisted of a student population of 1,628 for the 2010-2011 school year, with 383 of those students being in the 10th grade. With a broad range of diversity, the students for this year were 45% Caucasian, 1% Native American, 6% Hispanic, 18% African American, 18% Asian, 5% Middle Eastern, and 7% of Multi-Ethnic Origin. Worth noting within this broad spectrum of student ethnicities, Huron High School hosted 58 International students from 26 countries, and speaking 16 different languages.

With a record of outstanding student performance, Huron High School was selected as a 2010 Silver Medal selection for the 2010 *U.S. News and World Report's Best High Schools in America*. Previously, the school was also awarded the 2009 Best Overall Academic Performance

in Michigan by *Businessweek* magazine. Students consistently perform well on the State's standardized test, with the class of 2012 having 252 students, of 342, meeting or exceeding science standards, and of which 118 were rated advanced. Students typically exhibit an average ACT composite score between 24 and 25, with a vast majority of students being selected for admission to 4 year institutions of higher learning. Huron High School also has, on average, 20 students selected each year as National Merit Semi-Finalist, with the 2010-2011 school year also including the U.S. Department of Education selection of female Presidential Scholar for Michigan.

Students at Huron in the 10th grade are offered a choice between AC Physical Science or Earth Science as a science course selection. The students electing Earth Science often express less interest in science compared to their AC counterparts, but often display a wide range of academic abilities both within and outside of science. The sections of the course participating in this study represent the four sections taught by myself, out of the eight sections of the course offered by Huron High School this past year. While often expressing less enthusiasm for science than for other courses, the students joining Earth Science are normally active and willing participants.

With a sample size of 26, the assenting students represented 25% of the 104 Huron High School students within the Earth Science sections for which I was the instructor.

Implementation:

The 16 activities conducted during the course of this study were implemented throughout the 2010 – 2011 school year (Table 1). Each of the activities was executed in combination with the Earth Science chapter topic with which it was most closely correlated. Typically, the activities were performed on the Friday preceding the weekly Earth Science topic of interest. For each of the activities, a pre-test and post-test were performed in order to assess student comprehension and understanding of the correlated Earth Science topic for which the biological relevance was presented and explored (Table 2).

Each of the pre-test consisted of a *link* portion and 5 multiple-choice questions. The *link* (an acronym for list, inquire, note, and know) was an activity in which students take a moment to contemplate about the topic at hand, and list everything that comes to mind in regard to the subject matter. Students then shared a few of their prominent notions, and then inquired about and took notes on those they found enhanced their understanding. Students then summarized their findings into a knowledge statement to conclude the “know” segment of the *link*. Student responses to the multiple-choice questions were tabulated to indicate that the student either correctly or incorrectly indicated the proper response. The *link* portion was derived from the Ann Arbor district’s Reading Apprenticeship initiative, and is designated as a pre-reading strategy within this program.

After participating in the activity students submitted their post-test answers along with any pertinent forms from the lesson. As with the pre-tests, the post-tests consisted of five questions with responses tabulated to indicate student achievement.

Table 2. Activities and their associated High School Content Expectations

Activity	HSCEs
A. Closed Systems & BioBottle	E2.1A, E2.1B, E2.1C
B. Carbon & The Carbon Cycle	E2.3A, E2.3d, E2.2f
C. Nitrogen Runoff & The Nitrogen Cycle	E2.3b, E2.3c
F. Compass & Animal Migration	E3.2A
M. C-14 Dating	E5.3B, E5.3f
N. Index Fossils	E5.3D, E5.3x
L. History of Earth & Life Timeline	E5.3C
G. Volcanoes & Emerging Life	E3.4C, E3.4e
E. Soil Types & Plants	E3.p1B
H. Transpiration & The Water Cycle	E4.p1A
I. Wetlands & Aquatic Plants	E4.p1D
K. Lakes & Michigan Fishes	E4.1, E4.p3C
P. Rivers & Tree Distribution	E4.1, E4.p1C
J. Porosity & Permeability	E4.1B, E4.1C
D. CO ₂ v. Temperature	E5.4A, E5.4C, E5.4g, E5.r4j
O. Solar Energy per m ² & Sunprints	E5.2, E2.2A, E2.2B

Where applicable, the activities were conducted outside and in small groups in order to foster relevancy. The activities were designed to highlight a connection Earth Science shares

with Biology, particularly where a specific interaction between the biosphere and the other three Earth systems could be demonstrated. They were further developed to enhance student understanding of associated Michigan Earth Science high school content expectations (HSCEs). As the Table 2 illustrates, each endeavor was associated with one or more HSCEs, a unit of the Ann Arbor Public School's Earth Science curriculum, and a chapter from the course textbook, Earth Science by Holt McDougal publishers.

An Explanation of activities and their efficacy:

Closed Systems & The BioBottle (Appendix III-1):

Exemplifying the concepts of open and closed systems, students constructed closed micro ecosystems from a pair of 2 liter bottles. Modified from Bottle Biology (www.bottlebiology.org), with additional adaptations from the Science Teacher's Earth Systems in a Bottle, students formed miniature closed ecological systems using pop bottles, water, sand, soil, terrestrial plant seed, aquatic plants, and freshwater snails. Within this section, students presented the greatest gains in regard to understanding the response of an ecosystem to agents of change.

Carbon & The Carbon Cycle (Appendix III-2):

This activity introduced students to the carbon cycle and the various molecular forms of carbon that are present within the Earth's four systems. For each molecular form of carbon, sugar, carbon dioxide, carbon monoxide, methane, and calcium carbonate, students constructed a small molecular model from beads as guided by a provided card. Similar to the children's game "Pin the tail on the donkey", students were then instructed to affix their completed carbon based molecular model cards at appropriate locations on a supplied carbon cycle background. The background board gave students insight into the various carbon reservoirs found throughout the Earth's four systems. It also highlighted the biological carbon connections existing between the biosphere and the abiotic components of the Earth: the atmosphere, hydrosphere, and geosphere. Significant gains were demonstrated for student comprehension of the various molecular forms in which carbon may be found.

Nitrogen Runoff & The Nitrogen Cycle (Appendix III-3):

In order to exemplify the nitrogen cycle, and the problems that can be generated through excessive use of fertilizer within residential and industrialized agricultural systems, students applied various concentrations of nitrogen containing plant food to pond water samples. Students applied numerous science process skills within this lab, including measuring, diluting, observing, and writing in journals. Over the span of a week, students observed the inoculated samples for qualitative changes in algal growth. In learning about the nitrogen cycle, students collectively revealed new found knowledge concerning bacteria's function of fixing nitrogen within Earth systems as well as the ill effects fertilizers may impose upon the hydrosphere. In conjunction with the carbon cycle segment, student awareness of chemical flow through repositories within Earth systems was substantially elevated.

Compass & Animal Migration (Appendix III-6):

Students constructed compasses from assorted materials found within our classroom. Students magnetized a straightened paperclip and inserted it through a Styrofoam ball. The Styrofoam ball and magnetized paperclip assembly was placed into an inverted bottle cap filled with water. Free to rotate, the magnetized paperclip was observed by students as it indicated magnetic north and confirmed the presence of Earth's magnetic field. In conjunction with the pop bottle compass, students observed portions of National Geographic's video, Great Migrations, which indicated the possibility that insects and birds may have internal compasses also influenced by Earth's magnetism. Within this section occurred the single instance of regression for a pre- and post-test question pair. The question of concern queried students as to their knowledge of where in the Earth its magnetic field originates. Despite the instance of

regression, students exhibited gain in comprehending the characteristics of a magnet, as well as the geographic placement of the Earth's magnetic poles.

Carbon-14 Dating (Appendix III-13):

Using bingo chips as models of atomic decay, students explored the concept of radiometric decay and its use as a tool for measuring the passage of geological time. The chips, within a container, were shaken and placed on a table. Those chips that indicated decay were tabulated and removed, with the process cycling for seven rounds. Students utilized graphing skills, and worked in small groups to determine the mathematical relationships involved in the decay and timing correlation. The student sample showed significant improvement in their comprehension of radiometric decay, its usefulness as tool for measuring the passage of time, and the biological connections inherent when carbon is the element undergoing decomposition. Substantial growth was made in regard to student understanding of isotopes, as well as the radiometric concept of half-life.

Index Fossils (Appendix III-14):

With plastic models of fossils, students used a provided key to identify plastic models of fossils and worked in small groups to determine the ages of rock strata present on a backdrop of sedimentary layers from which the fossils were obtained. The students also explored a variety of extinct forms of life representative of selected periods from Earth's history. Corresponding with the aspirations of forming connections between Earth Science and Biology, this portion of the study demonstrated for students the association between Earth's geologic record and the fossils of its biological past.

History of the Earth & Timeline (Appendix III-12):

The students, working in small collaborative groups, produced timelines of Earth's history, highlighting the occurrences of the formation of the Earth, the formation of an oxygen atmosphere, the rise of life, the Cretaceous-Tertiary (K-T) and Permian extinctions, as well as the Pleistocene ice age. Employing their course textbook as a source, students generated the timeline to scale on meters-long strips of adding machine paper rolls. Students were instructed to produce aesthetically pleasing products that included the use of illustration, clearly demarcated the divisions of time (Eons, Eras, Periods, and Epochs), demonstrated the enormity of scale, and highlighted significant events in Earth's history beyond those previously listed. The students presented the greatest gains in regard to understanding the nomenclature pertinent to geologic time as well as the vast scale of time involved in the planet's past.

Volcanoes & Emerging Life (Appendix III-7):

Reading a selected article, Mountain Transformed, from the May 2010 issue of National Geographic, students discussed in small groups the devastation and alterations volcanoes can impose on the biosphere. In connection with the reading and small group discussions, students completed a series of guided reading questions related to the article. Students were further requested to produce illustrations of how other natural events could exhibit disruptions to the biosphere. Yielding the largest gains in comprehension within this section was the knowledge that igneous rock is most closely related to volcanic activity.

Soil Types & Plants (Appendix III-5):

Employing soil-sampling tools students collected, sifted, and analyzed soil samples for their composition in regard to particle size. Through utilizing a soil triangle, students were able to determine the soil type from the percentage of silt, sand, and clay present in their collected sample. Students formed a variety of soil types by combining sand, silt, and clay in defined proportions. These generated soil samples were then planted with green bean seeds (*Phaseolus vulgaris* L.), from which students derived observations focusing on germination, growth, and healthy development of the plants. Showing greatest gain within this section was student awareness of the components, particularly those that are organic, constituting soil.

Transpiration & The Water Cycle (Appendix III-8):

After identifying selected trees adjacent to our school building, the students used large clear plastic bags to cover a selection of leaves. The bags were left on for a 24-hour period, during which the water released by transpiration was collected. Students then compared the amounts of water obtained from the various species of trees. Supplementary information regarding transpiration and its role in the water cycle was also provided. Commensurate with the aim of this study, students exhibited substantial growth in understanding the contribution to the water cycle plants make through transpiration.

Wetlands & Aquatic Plants (Appendix III-9):

Using Wetland Plants of Michigan by Steve Chadde, students identified a wide variety of plants found within Ann Arbor's Gallup Park. Having taken digital pictures of the plants during the outing, small groups of students shared selected botanical photos with the class. Within this section were notable student gains in comprehending the Earth Science concepts of floodplains and watersheds.

Lakes & Michigan Fishes (Appendix III-11):

The students employed Dave Bosanko's Fish of Michigan Field Guide in order to identify a variety of preserved fish specimens native to Michigan. In addition, students used the internet to uncover information in regard to Michigan's fish hatcheries. The students displayed significant gains in regard to Great Lakes knowledge, and specifically showed a deeper understanding of the detriment posed by invasive species within these vast surface waters.

Rivers & Tree Distribution (Appendix III-16):

Discerning a relationship between tree distribution and surface water, in particular the Huron River, students plotted the location of identified trees. Using provided handheld GPS units, the location and species of 5 different trees each were collected by small collaborative groups. The collected data were then uploaded for digital mapping from which the collective tree locations could be observed. Students displayed clear knowledge of the conditions required for rivers to form, as well as the connection between these surface waters and their arboreal surroundings.

Porosity & Permeability (Appendix III-10):

Constructing an aquifer model from 60 milliliter syringes, sand, and gravel, students explored the concepts of porosity and permeability. Adding water to the syringe as it contained a predetermine volume of sand, gravel, or combination thereof, students observed how much fluid the system (a capped syringe with 50 mL of substrate) could hold. Conducting this procedure three times, students then averaged their findings to determine the vessel's contents. For the

second segment of the activity, students determined permeability by timing the flow of fluid through the system. This portion was also conducted three times per group, with the results averaged to determine a flow rate expressed in milliliters per minute. Learning both the concepts of porosity and permeability, students demonstrated significant gains in understanding groundwater flow.

CO₂ vs. Temperature (Appendix III-4):

Another activity making use of 2 liter soda pop bottles, this exploration sought to discern the difference in temperature change experienced by common air when compared with a equal volume sample of carbon dioxide. The students were provided complementary information regarding the Global Warming Potential (GWP) of various gases known to exacerbate the greenhouse effect within the atmosphere. Having predicted which of the gases might be affected by exposure to solar radiation first, and having calculated estimates of heat absorption observed through temperature change, the students placed the two bottles next to each other outside. The bottles were placed in such a manner as to ensure equal exposure to sunlight. Furthermore, bottles were selected that were clear and completely absent of their former commercial labeling to control for potential differences inherent in the containers. As a preview to their impending year in Chemistry, and in the desire of acknowledging the obligation for safety, students also explored the use of the Ideal Gas Law in foretelling the characteristics of a gas sample when confined to a 2-liter volume. Students demonstrated knowledge of factors contributing to increased atmospheric greenhouse gas concentrations and the sources of data used by paleoclimatologists.

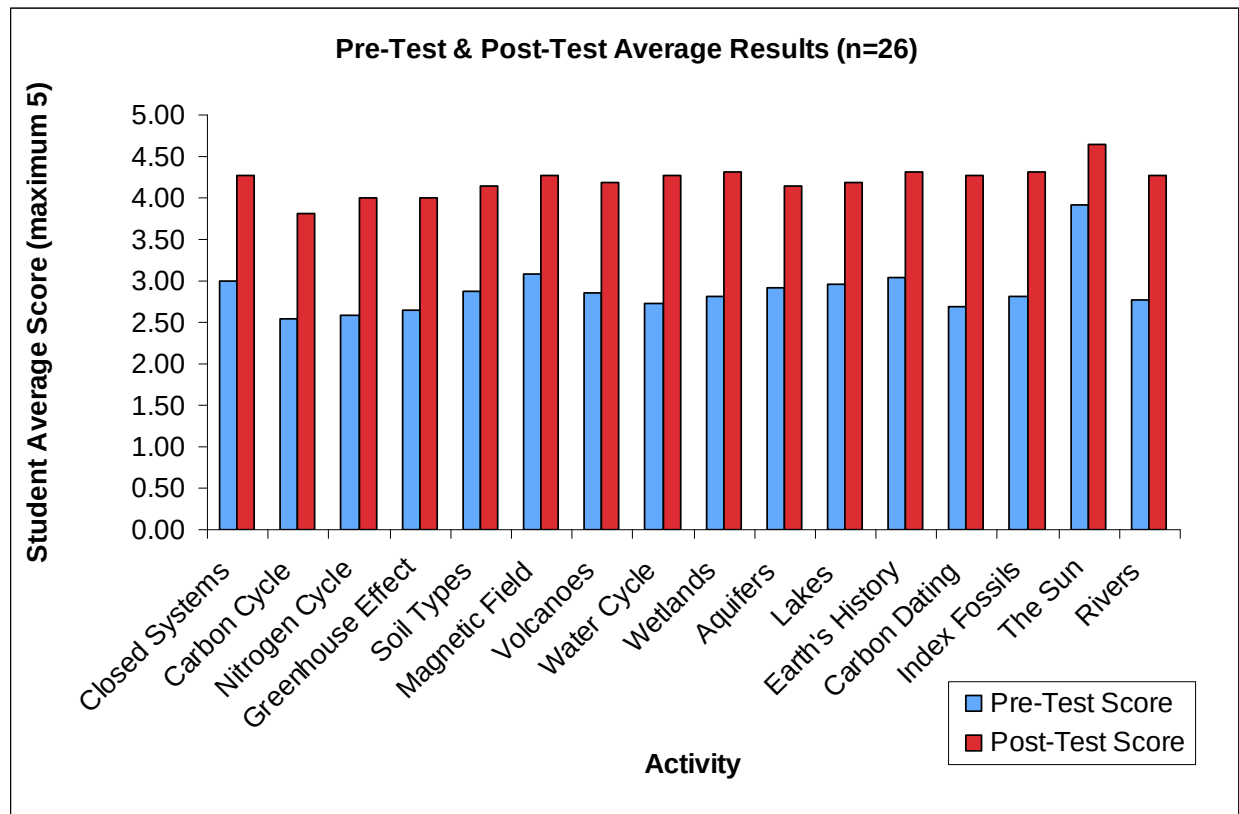
Solar Energy per m² & Sunprints (Appendix III-15):

Uniting the endeavors of Science and Art, the students produced sunprints, or cyanotypes, of flowers, grasses, leaves, and other materials of interest. Assisting with instruction during this activity was a student teacher from Eastern Michigan University. In addition to the artistic print produced by each student, a 1 inch wide strip of the cyanotype paper was removed from the original sheet and used to observe variation produced by different exposure times. 1 inch segments of the strip were exposed with a 2 minute time difference between initiation of exposure per section. Information regarding the cyanotype technique was obtained from [Alternative Photography](http://www.alternativephotography.com), a website on historical photographic methods (www.alternativephotography.com). Significant input regarding implementation of this activity, as well as use of cyanotyping, was provided by Dr. Ken Nadler. This section displayed specific student gains in understanding the Sun's role as the Earth's primary source of energy, and that plants are able to convert this energy into forms useable by other segments of the biosphere.

Results and Evaluation:

Assessment of the 16 activities occurred through use of pre-test and post-test evaluations. Each test consisted of five questions related to the activity and its associated Earth Science topic. Across all of the activities students displayed improvement through increased scores as they progressed from each pre-test to post-test. On average, per activity, students exhibited 26.5% in average growth when compared to the total points possible on each assessment. Figure 1 illustrates the student averages for pre-test and post-test scores as well as the percentage gains made on a per activity basis. As indicated by their pre-test scores, students exhibited a substantial amount of prior knowledge.

Figure 1. Student averages for pre-test and post-test scores by activity. For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.



All of the students assenting to the study (n=26) showed progress, with only one question pair out of the eighty conducted displaying an instance of regression.

Paired t-test were performed on each of the activities' pre-test/post-test combinations to determine if the activities were significant in affecting student comprehension and imparting relevance between Earth Science and Biology.

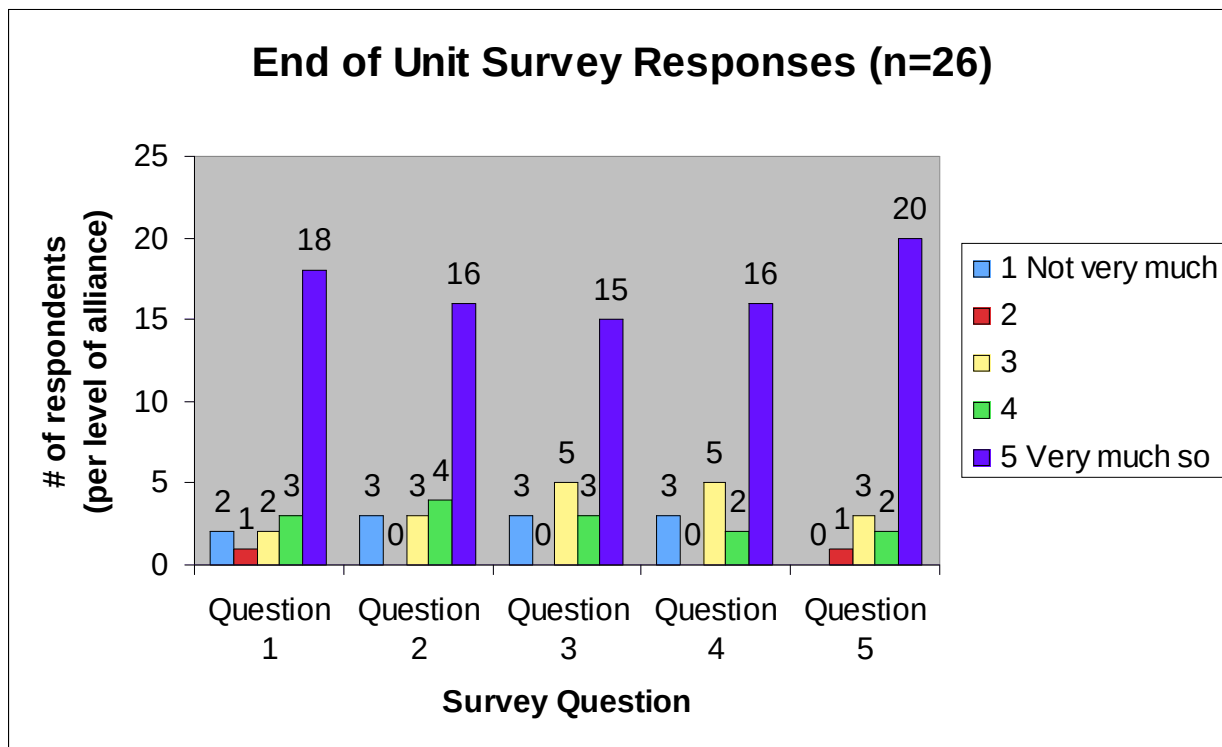
From the collected paired t-test data it is noted that all of the activity assessment pairs yielded p-values of 0.00. T-values for the 16 activities presented an average of -7.60. Displayed within Table 3 are the t and p values for the individual activities conducted during the study:

Table 3.: t and P values for the conducted activities (n=26).

Activity	t-value	P-value
Closed Systems	-7.40	0.00
Carbon Cycle	-7.40	0.00
Nitrogen Cycle	-7.35	0.00
Greenhouse Effect	-7.70	0.00
Soil Types	-8.32	0.00
Magnetic Field	-7.59	0.00
Volcanoes	-7.34	0.00
Water Cycle	-9.67	0.00
Wetlands	-7.73	0.00
Aquifers	-7.70	0.00
Lakes	-7.70	0.00
Earth's History	-7.82	0.00
Carbon Dating	-8.15	0.00
Index Fossils	-6.93	0.00
The Sun	-4.79	0.00
Rivers	-8.06	0.00

Providing student perceptions in regard to the activities, a survey pertinent to the study (Appendix II: End of Unit Survey) was conducted in conjunction with other (district mandated) student course evaluations, the results of which are present in Figure 2.

Figure 2.: End of Unit Survey Results



When inquired as to whether the conducted activities were enjoyable 18 of the 26 students responded very much so, with an additional 3 responding affirmatively. 20 of the students assenting to the study indicated the activities showed for them the importance of Earth Science to living things. Most of the students (18 of 26) replied that the lessons were commensurate with the topic at hand, and that after participation they felt Earth Science was of importance to them. Overwhelmingly students indicated that Earth Science and the other science disciplines have much in common.

Discussion and Conclusion:

Imparting a sense of relevancy for secondary students in regard to any science course, particularly within Earth Science, can be a complex task. Uniting Earth Science topics to biological concepts with which students have prior knowledge and experience can facilitate opportunities for students to consider the relationship shared between Earth Science, Biology, their lives, and the greater world around them. Being able to connect new scientific knowledge with their past experiences aids students in observing the broader context of the implications science, such as Biology and Earth Science, may have on their existence. Further, these ties validate both their prior knowledge as indicated through pre-assessment (Figure 1), and the new concepts to which they are exposed, thus corroborating the importance and intertwined nature of science as demonstrated by both post-assessments and the end of unit survey (Klemm, 2008).

Connecting the concepts of one science subject with another, as in this study's instance with Biology and Earth Science, is one way of enhancing relevancy for students, but not likely the only means. To ensure that the tactic of employing prior biological knowledge and experience was not undermined by lack of attention to other factors indicated as implicit in generating science relevancy for students, it was imperative to include these aspects as well. Among these components were the many opportunities for students to engage in authentic scientific investigations, participate scientifically within their local neighborhood, explore issues of contemporary importance, practice science process skills, and share in cooperative learning with their peers (Newton, 1988). The activities employed provided students with occasions in which to authentically engage in science, a demonstrated means through which students connect with the discipline and grasp the means by which professionals conduct investigations (Kastens,

2008). Examples of such engagement include the use of geological instruments and the opportunity to explore science outdoors, outside of the confines of the classroom.

The chance to conduct inquiry regarding variables, which could potentially affect the experimental outcome, in an open manner, invoked feelings of ownership among students in the learning process (Hermann, 2010). Using the local environment surrounding their school as a location of study within the transpiration and CO₂ activities appealed to the students, and imparted to them that science has the potential to be an integral part of their lives (Black, 2004). Conducting our investigations around current issues, both local and global, enhanced for students the relevance it has on their environment and community (Wilmes, 2009). Students further expressed increased participation and interest wherein the activities allowed for cooperative learning and academically appropriate opportunities for socialization (Chang, 1999).

The pre- and post-test assessments (Figure 1) indicate that the employed activities had a positive influence on student understanding of, and appreciation for, the presented Earth Science topics and their biological connections. Students collectively demonstrated significant advancement in all but one of the eighty question pairs, only regressing by one response in relation to the Earth's magnetic field and its place of origin. Among the participating students, the average percent increase (26.5%) of correct responses between pre- and post- assessments signifies the conducted lessons were significantly effective in augmenting students' Earth Science knowledge through the application of activities with biologically relevant connections.

The activities included hands on opportunities to conduct science in the field, calling on students to utilize science process skills and participate in numerous settings beyond the classroom walls. By engaging in an acquisitive, organized, creative, and communicative manner, students did express feelings of achievement and academic fulfillment through their

Earth Science experience as evidenced by their end of unit survey responses. Providing the students with an engaging and relevant Earth Science experience certainly required incorporating lessons with opportunity for inquiry and student reflection on the connections in the natural world that span the science disciplines (DeFina, 2006).

The End of Unit Survey provided additional anecdotal evidence of student appreciation for Earth Science and its relevancy to their lives. As indicated in Figure 2, 65% of students indicated on average that they felt an increased sense of importance regarding Earth Science. 69% of students expressed enjoyment in the activities, and beyond the survey expressed a desire for more opportunities for similar scientific inquiry. Students further indicated that the activities were relevant and conveyed the importance of Earth Science. Also articulated was their understanding that the various disciplines within science share common features, and are intertwined by the many concepts that span across them.

As with any educational endeavor, the collection of activities presented within this study, and their implementation, present opportunities for improved delivery. Each activity, with perhaps the exception of Index Fossils, was intended to be implemented in a fashion that would be brief, succinct, and as directly relevant to the Earth Science topic at hand during which they were executed. As an educator, observing the moments the activities provided which were engaging, informative, and at times even entertaining, were of sufficient evidence that their integration into the course was of worth. It is the anticipation of future students, eager to find relevance in the science they are charged with learning, which assures continued use of these activities in addition to the continued search for new ways to provide connections across the science curriculum.

APPENDICES

APPENDIX I

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

PARENTAL CONSENT AND STUDENT ASSENT FORM

Dear Students and Parents/Guardians:

I am a graduate student in Michigan State University's Division of Science and Mathematics Education. My thesis research is on enhancing the relevance of Earth Science for students through the use of Biology related activities. My purpose for this research is to better understand how to improve the quality of Earth Science instruction.

Data for the study will be collected from student work generated in the course of participation in our Earth Science class, and will include items such as pre- and post-test, lab activities, and surveys. I am asking for your permission to include your child's data in my thesis. Your child's confidentiality is a foremost concern. During the study I will collect and reproduce student work. These assignments will have the students' names removed prior to inclusion within the study. All of the work being collected will be stored and locked in my office until the completion of the study, at which time it will be shredded. Additionally, your child's identity will not be attached to any data in my thesis paper or in any images used in the thesis presentation. Instead, the data will consist of class averages and samples of student work that do not include names. Confidentiality of records will be maintained throughout the course of my study and beyond. Michigan State University requires that research records must be maintained for a minimum of three years following completion of the study. During this time, only myself, my advisor, and the Institutional Review Board of Michigan State University will have access to these records. Your child's confidentiality will be protected to the maximum extent allowable by law.

Participation in the study is completely voluntary, and you may withdraw your participation at any time. If either the student or their parent request to withdraw, the student's information will not be used in this study. All students will be required to complete all of the given class assignments and activities. There are no unique research activities – participation in this study will not increase or decrease the amount of work that students do. I will simply reproduce copies of students' work for my research purposes. Students who do not participate in the study will not be penalized in any way. In fact, I will not know who is or is not included in the study until the end of the school year, after all grades have been submitted.

There are no known risks associated with participating in this study. In fact, completing course work should be very beneficial to students. I will minimize any risk that may exist by having another person collect and store the consent forms in a locked file cabinet that will not be opened until after the end of the school year. That way I will not know who agrees to participate in the research until after the grades are issued. In the meantime, I will save all written work relevant to the study. Later, I will analyze the written work only for students who have agreed to participate in the study and whose parents/guardians have consented.

If you are willing to allow your child to participate in the study, please complete the attached form and return it to Mr. Russell in Room 5204. Please seal the form in the provided envelope. The envelopes will be stored in a locked cabinet and opened after the completion of the school year.

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact me by mail at Mr. Michael Damron, Huron High School, 2727 Fuller Rd., Ann Arbor, Michigan 48105, by email at damronm@aaps.k12.mi.us, or by phone at (734) 997-1900 x37540. Questions about the study may also be directed to Dr. Merle Heidemann at Michigan State University's Division of Science and Mathematics Education via email: heidema2@msu.edu, by phone: (517) 432-2152, or by mail at 118 N. Kedzie East Lansing, Michigan 48824. If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – the Michigan State University's Human Research Protection Program at (517) 355-2180, Fax: (517) 432-4503, email: irb@msu.edu, or mail: 207 Olds Hall, Michigan State University, East Lansing, Michigan 48824.

Thank you,

Mr. Michael Damron
Science Teacher, Huron High School

Earth Science & Biology Connections: Enhancing Earth Science Relevance for
Students through Biological Explorations

PARENTAL CONSENT AND STUDENT ASSENT FORM

M. Damron
Huron High School
Ann Arbor, MI

Parents/Guardians should complete this following consent information:

I voluntarily agree to allow _____ to participate in this study.
(print student name)

Please check all that apply:

Data:

_____ I give Mr. Damron permission to use data generated from my child's work in this class for his thesis project. All data from my child shall remain confidential.

_____ I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be graded in the same manner regardless of their participation in this study.

Photography / Videotaping:

_____ I give Mr. Damron permission to use pictures or videos of my child participating in activities while in Earth Science class. I understand that my child will not be identified by name in either photos or videos.

_____ I do not wish to have my child's images used at any time during this thesis project.

Signatures:

(Parent / Guardian Signature) (Date)

I voluntarily agree to participate in this thesis project.

(Student Signature) (Date)

***** Important *****

Please return this form to Mr. Russell in Room 5204

APPENDIX II

Earth Science Pre-Test: Closed Systems

LINK: SYSTEM			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

- How does the transfer of energy throughout an ecosystem begin?
A. Human pollution B. Plants, solar energy, and photosynthesis *
C. Energy depletion D. Producers eating consumers
- Ecosystems respond to change by:
A. decomposing B. revolving
C. returning to balance * D. dying
- Which of the following are examples of energy and matter movement:
A. All of these * B. Nitrogen Cycle
C. Carbon Cycle D. Phosphorus Cycle
- A system in which matter and energy are freely exchanged with surroundings:
A. Closed System B. Sound System
C. Energy System D. Open System *
- A system in which energy, but not matter, is exchanged with surroundings:
A. Closed System * B. Sound System
C. Energy System D. Open System

Earth Science Post-Test: Closed Systems

Questions:

1. How does the transfer of energy throughout an ecosystem begin?
A. Human pollution B. Plants, solar energy, and photosynthesis *
C. Energy depletion D. Producers eating consumers
2. Ecosystems respond to change by:
A. decomposing B. revolving
C. returning to balance * D. dying
3. Which of the following are examples of energy and matter movement:
A. All of these * B. Nitrogen Cycle
C. Carbon Cycle D. Phosphorus Cycle
4. A system in which matter and energy are freely exchanged with surroundings:
A. Closed System B. Sound System
C. Energy System D. Open System *
5. A system in which energy, but not matter, is exchanged with surroundings:
A. Closed System * B. Sound System
C. Energy System D. Open System

Earth Science Pre-Test: Carbon Cycle

LINK: CARBON			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

- Through which of the following reservoirs does carbon move?
A. Atmosphere B. Hydrosphere
C. Biosphere D. All of these *
- Carbon is stored as a rock, carbonate, in the:
A. Biosphere B. Atmosphere
C. Geosphere * D. Hydrosphere
- Chemically, carbon can connect with ____ atoms at once.:
A. five B. seven
C. two D. four *
- Which of the following are molecular forms of carbon:
A. Methane B. Carbon dioxide
C. Calcium carbonate D. All of these *
- When they die, marine organisms often contribute to forming:
A. Methane B. Carbon dioxide
C. Calcium carbonate * D. Carbohydrates

Earth Science Post-Test: Carbon Cycle

Questions:

1. List the Earth Systems that carbon passes through within the carbon cycle:

2. Carbon is stored as a rock, carbonate, in the _____.

3. Chemically, carbon can connect with _____ atoms at once.

4. What are 3 examples of carbon containing molecules?

5. When they die, marine organisms often contribute in forming

Earth Science Pre-Test: Nitrogen Cycle

LINK: CYCLE			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. Nitrogen is found in living things?
True * / False
2. Nitrogen, as fertilizer run-off, often pollutes the:
A. Atmosphere B. Geosphere
C. Hydrosphere * D. All of these
3. Nitrogen is the majority component of the:
A. Atmosphere * B. Geosphere
C. Hydrosphere D. Biosphere
4. Which of these are nitrogen-containing molecules:
A. Nitrates B. Nitrites
C. Ammonium D. All of these *
5. Nitrogen is fixed in the biosphere by:
A. decomposers B. bacteria *
C. plants D. rabbits

Earth Science Post-Test: Nitrogen Cycle

Questions:

1. Nitrogen is found in living things?
True * / False

2. Nitrogen, as fertilizer run-off, often pollutes the:
A. Atmosphere B. Geosphere
C. Hydrosphere * D. All of these

3. Nitrogen is the majority component of the:
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C. Hydrosphere D. Biosphere

4. Which of these are nitrogen-containing molecules:
A. Nitrates B. Nitrites
C. Ammonium D. All of these *

5. Nitrogen is fixed in the biosphere by:
A. decomposers B. bacteria *
C. plants D. rabbits

Earth Science Pre-Test: Greenhouse Gases

LINK: GLOBAL WARMING			
List	Inquire	Notes	Knowledge

Questions:

1. A gradual increase in the average global temperature, due to greenhouse gases:
A. Arctic climate B. global warming *
C. solar energy D. microclimate
2. Used in a method of measuring past climates in which high CO₂ points to warmer temperatures:
A. fossils B. quartz
C. solar energy D. ice cores *
3. According to Milankovitch, this does not cause climate change:
A. Earth's orbital change B. Earth's tilt
C. Axial wobble D. tectonic plates *
4. Which will not help reduce CO₂ concentrations in the atmosphere?
A. recycling B. turning up the heat in the winter *
C. using less electricity D. driving a more efficient car
5. Two major factors used to describe climate are:
A. precipitation and temperature * B. global and warming
C. wind and temperature D. wind and tides

Earth Science Post-Test: Greenhouse Gases

Questions:

1. A gradual increase in the average global temperature, due to greenhouse gases:
A. Arctic climate B. global warming *
C. solar energy D. microclimate

2. Used in a method of measuring past climates in which high CO₂ points to warmer temperatures:
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C. Axial wobble D. tectonic plates *

4. Which will not help reduce CO₂ concentrations in the atmosphere?
A. recycling B. turning up the heat in the winter *
C. using less electricity D. driving a more efficient car

5. Two major factors used to describe climate are:
A. precipitation and temperature * B. global and warming
C. wind and temperature D. wind and tides

Earth Science Pre-Test: Soil Types

LINK: SOIL			
List	Inquire	Notes	Knowledge

Questions:

1. The layer of weathered rock that covers most of the Earth's surface:
A. Soil
B. Regolith *
C. Horizon
D. Producers
2. A complex mixture of minerals, water, gases, and organic material:
A. Soil *
B. Regolith
C. Horizon
D. Producers
3. To determine soil types, a soil triangle compares percentages of:
A. Sand
B. Silt
C. Clay
D. All of these *
4. Parent rock rich in quartz produces soil containing a lot of:
A. Sand *
B. Silt
C. Clay
D. Iron
5. A horizontal layer of soil clearly different than that above or below it:
A. Rock
B. Regolith
C. Horizon *
D. Clay

Earth Science Post-Test: Soil Types

Questions:

1. The layer of weathered rock that covers most of the Earth's surface:
A. Soil
B. Regolith *
C. Horizon
D. Producers

2. A complex mixture of minerals, water, gases, and organic material:
A. Soil *
B. Regolith
C. Horizon
D. Producers

3. To determine soil types, a soil triangle compares percentages of:
A. Sand
B. Silt
C. Clay
D. All of these *

4. Parent rock rich in quartz produces soil containing a lot of:
A. Sand *
B. Silt
C. Clay
D. Iron

5. A horizontal layer of soil clearly different than that above or below it:
A. Rock
B. Regolith
C. Horizon *
D. Clay

Earth Science Pre-Test: Magnetic Field

LINK: MAGNETIC			
List	Inquire	Notes	Knowledge

Questions:

- Which of the following is a likely source of Earth's magnetism?
A. The Iron Core * B. The Sun
C. The Moon D. The Oceans
- Magnets have ____ poles:
A. Three B. Two *
C. no D. Four
- The Earth's magnetic north pole is located at the geographic north pole?
True / False
- The Earth's magnetic field can be affected by:
A. nothing B. the tides
C. wind D. the Sun *
- Animals can use the Earth's magnetic field as a reference for navigation?
True / False

Earth Science Post-Test: Magnetic Field

Questions:

1. Which of the following is a likely source of Earth's magnetism?
A. The Iron Core * B. The Sun
C. The Moon D. The Oceans

2. Magnets have _____ poles.

3. The Earth's magnetic south pole is located at the geographic North Pole?
True / False

4. The Earth's magnetic field can be affected by:
A. nothing B. the tides
C. wind D. the Sun *

5. Animals can use the Earth's magnetic field as a reference for navigation?
True / False

Earth Science Pre-Test: Volcanoes

LINK: VOLCANOES			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. The type of rock that forms when magma cools and hardens:
A. Igneous * B. Sedimentary
C. Lava D. Metamorphic
2. A volcanically active area, often far from a plate boundary:
A. lapilli B. pluton
C. hot spot * D. planet vulcan
3. Which of the following is not a major volcano cone type?
A. Cinder B. Composite
C. Shield D. Mantle *
4. Pyroclastic materials include:
A. Ash B. Bombs
C. Lapilli D. All of these *
5. The eruption of Mount St. Helens was:
A. stratovolcanic B. quiet
C. explosive * D. oceanic

Earth Science Post-Test: Volcanoes

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Earth Science Pre-Test: Water Cycle

LINK: WATER			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

- Any form of water that falls to the Earth's surface:
A. Precipitation * B. Condensation
C. Evaporation D. Transpiration
- Transpiration is water released by:
A. Clouds B. Plants *
C. Factories D. Rivers
- Which of these may affect the local water budget:
A. temperature B. vegetation
C. rainfall D. all of these *
- The process by which liquid water turns into water vapor is:
A. Precipitation B. Condensation
C. Evaporation * D. Transpiration
- The change of state from a gas to a liquid:
A. Precipitation B. Condensation *
C. Evaporation D. Transpiration

Earth Science Post-Test: Water Cycle

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Earth Science Pre-Test: Wetlands

LINK: SWAMP			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. An area drained by a river systems is a:
A. precipitate B. watershed *
C. floodplain D. tectonic plate
2. The land area that may be covered with water when a river overflows:
A. precipitate B. watershed
C. floodplain * D. tectonic plate
3. An artificial levee is a form of:
A. flood control * B. pollution control
C. evapotranspiration D. ecology
4. Wetlands often serve as a natural means of water:
A. purification * B. erosion
C. salinization D. depletion
5. Types of wetlands include:
A. swamps B. marshes
C. bogs D. all of these *

Earth Science Post-Test: Wetlands

Questions:

1. An area drained by a river systems is a:
A. precipitate B. watershed *
C. floodplain D. tectonic plate

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A. purification * B. erosion
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C. bogs D. all of these *

Earth Science Pre-Test: Aquifers

LINK: GROUNDWATER			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. The ability of rock (or soil) to let water pass through its pores:
A. artesian B. permeability *
C. gradient D. aquifer
2. The percentage of the total volume of rock consisting of open space:
A. porosity * B. revolving
C. karst D. water table
3. The upper boundary of the zone of saturation:
A. porosity B. revolving
C. karst D. water table *
4. The steepness of a slope:
A. porosity B. gradient *
C. karst D. water table
5. A body of rock (and soil) that stores underground water and lets it flow:
A. porosity B. revolving
C. aquifer * D. water table

Earth Science Post-Test: Aquifers

Questions:

1. The ability of rock (or soil) to let water pass through its pores is

2. The percentage of the total volume of rock consisting of open space is

3. The upper boundary of the zone of saturation is the

4. _____ is the steepness of a slope.

5. A body of rock (and soil) that stores underground water and lets it flow is

Earth Science Pre-Test: Lakes

LINK: GREAT LAKES			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

- Which of the following is not a way to ensure future water supplies?
A. limit use B. enforce antipollution laws
C. increase wastewater * D. enforce conservation laws
- The Great Lakes include:
A. Lake Huron B. Lake Michigan
C. Lake Ontario D. all of these *
- The water that is lost from an area:
A. precipitation B. erosion
C. evapotranspiration * D. sublimation
- Nitrogen may act as a pollutant in lakes in the form of:
A. fertilizer runoff * B. carbon dioxide
C. plastic D. all of these
- One invasive species threatening the great lakes is:
A. Asian carp * B. bluegill
C. seagulls D. emerald ash borer

Earth Science Post-Test: Lakes

Questions:

1. Which of the following is not a way to ensure future water supplies?
A. limit use B. enforce antipollution laws
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A. fertilizer runoff * B. carbon dioxide
C. plastic D. all of these

5. One invasive species threatening the great lakes is:
A. Asian carp * B. bluegill
C. seagulls D. emerald ash borer

Earth Science Pre-Test: History of the Earth

<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. Geologic time is divided into

A. two eons	B. three eons
C. four eons *	D. five eons

2. Geologic periods are often named for the

A. fossils	B. person describing it.
C. types of plants	D. place where its fossils were discovered *

3. A table that outlines the development of the Earth:

A. Geologic time scale *	B. period
C. eras	D. eons

4. The Earth is approximately:

A. two million years old	B. 7 trillion years old
C. 4.6 billion years old *	D. five hundred thousand years old

5. Sharks appeared on the geologic time scale before the dinosaurs.

True *	False
--------	-------

Earth Science Post-Test: History of the Earth

Questions:

1. Geologic time is divided into
 - A. two eons
 - B. three eons
 - C. four eons *
 - D. five eons

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 - D. eons

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 - A. two million years old
 - B. 7 trillion years old
 - C. 4.6 billion years old *
 - D. five hundred thousand years old

5. Sharks appeared on the geologic time scale before the dinosaurs.
True * / False

Earth Science Pre-Test: Carbon Dating

LINK: RADIOACTIVE			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

- Carbon-14 is an isotope:
 - for objects <70K years old *
 - formed by radioactive decay.
 - for objects >6K years old
 - that cannot be used to date objects
- The time it takes for half of a sample of radioactive isotope to decay:
 - decay time
 - radiometric dating
 - half-life *
 - alpha decay
- The numeric age of an object:
 - relative age
 - radiometric time
 - half-life
 - absolute age *
- Determining the age of an object through comparison of isotopes:
 - decay time
 - radiometric dating *
 - half-life
 - alpha decay
- What isotopes are compared to determine the absolute age of a rock?
 - parent vs. daughter isotopes *
 - sister isotopes
 - isotopes of different rocks
 - non-radioactive

Earth Science Post-Test: Carbon Dating

Questions:

1. Carbon-14 is an isotope used to date material
_____ years old.
2. The time it takes for half of a sample of radioactive isotope to decay is a
_____.
3. The numeric age of an object is its _____ age.
4. _____ is the process of determining the age of an object
through comparison of isotopes.
5. _____ and _____ isotopes
are compared to determine the age of material.

Earth Science Pre-Test: Index Fossils

LINK: FOSSILS			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. What is amber?
A. frozen organic matter B. dead bacteria
C. tar that traps animals D. tree sap that fossilizes insects *
2. What is coprolite?
A. fossilized fish B. fossilized animal waste *
C. metamorphic rock D. fossilized animal imprints
3. The way fossils are formed in very dry places is called:
A. mummification B. petrification *
C. imprinting D. sedimentation
4. Varves are very much like:
A. Tree rings * B. petrification
C. clouds D. sedimentation
5. A fossil used to date a rock layer is a:
A. trace fossil B. igneous deposit
C. index fossil * D. disconformity

Earth Science Post-Test: Index Fossils

Questions:

1. Amber is _____ that fossilizes insects.
2. What is coprolite?
A. fossilized fish B. fossilized animal waste *
C. metamorphic rock D. fossilized animal imprints
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Earth Science Pre-Test: The Sun

LINK: SUNLIGHT			
List	Inquire	Notes	Knowledge

Questions:

- The Sun's energy is a result of
 - nuclear proliferation
 - nuclear disaster
 - nuclear depletion
 - nuclear fusion *
- Particles thrown off the sun's corona affecting Earth's magnetic field:
 - Coronal mass ejection *
 - nuclear disaster
 - Sunspot
 - Comet
- Violent, explosive release of solar energy:
 - Asteroid
 - Sun cycle
 - nuclear depletion
 - nuclear fusion
- How long is the average sunspot cycle?
 - 3 days
 - 5 weeks
 - 11 years *
 - 12 months
- The process by which plants convert solar energy into stored chemical energy:
 - photosynthesis *
 - dehydration
 - combustion
 - nuclear fusion

Earth Science Post-Test: The Sun

Questions:

1. The Sun's energy is a result of
 - A. nuclear proliferation
 - B. nuclear disaster
 - C. nuclear depletion
 - D. nuclear fusion *

2. Particles thrown off the sun's corona affecting Earth's magnetic field:
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 - D. Comet

3. Violent, explosive release of solar energy:
 - A. Asteroid
 - B. Sun cycle
 - C. nuclear depletion
 - D. nuclear fusion

4. How long is the average sunspot cycle?
 - A. 3 days
 - B. 5 weeks
 - C. 11 years *
 - D. 12 months

5. The process by which plants convert solar energy into stored chemical energy:
 - A. photosynthesis *
 - B. dehydration
 - C. combustion
 - D. nuclear fusion

Earth Science Pre-Test: Rivers

LINK: HURON RIVER			
<i>List</i>	<i>Inquire</i>	<i>Notes</i>	<i>Knowledge</i>

Questions:

1. How does a river's velocity affect its erosive ability?

A. slower rivers erode more quickly
B. faster rivers erode more quickly *

C. faster rivers are less erosive
D. slower rivers are more erosive

2. The main condition needed for a river to develop is:

A. a balanced water budget
B. precipitation exceeds evapotranspiration*

C. less condensation
D. dry weather

3. Which of the following factors widen and deepen a river channel?

A. load, discharge, gradient
B. meanders, watersheds, divides

C. acidity, sediment, erosion *
D. fish, organic sediment, soil

4. What is a tributary?

A. a dry stream bed
B. a stream feeding another stream *

C. a lake feeding a stream
D. a song about rivers

5. A fan shaped mass of rock formed by a river:

A. Alluvial fan*
B. science fan

C. river fan
D. rock fan

Earth Science Post-Test: Rivers

Questions:

1. How does a river's velocity affect its erosive ability?
A. slower rivers erode more quickly B. faster rivers erode more quickly *
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A. Alluvial fan* B. science fan
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Earth Science & Biology Connections: Enhancing Earth Science Relevance for
Students Through Biological Explorations

End of Unit Survey

Survey Questions: Circle a numbered response to the questions below.

1. I enjoyed the activities for this unit:

Not very much - 1 2 3 4 5 - I really liked it.

2. The unit and activities showed me the importance of Earth Science to living things.

Not very much - 1 2 3 4 5 - Very much so.

3. The activities used were very relevant to the unit topic.

Not very much - 1 2 3 4 5 - Very much so.

4. After participating in these activities and unit I feel Earth Science is important to me.

Not very much - 1 2 3 4 5 - Very much so.

5. I feel that Earth Science and other sciences have a lot in common.

Not very much - 1 2 3 4 5 - Very much so.

Other Comments:

APPENDIX III

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 1

Closed Systems & BioBottles

Introduction: In forming a micro ecosystem, students will generate an example of a closed system within a pair of 2L bottles.

Materials: BioBottle Guide (www.bottlebiology.org & Earth Systems in a Bottle)
2L Pop Bottles (2 per group)
Craft supplies (Scissors, Tape)
Sand & Soil Funnel
Bean Seeds
Elodea
Freshwater Snails

Directions: Construct the bottle system as follows:

1. Cut the top (cap end) off 1 bottle
2. With assistance, drill holes in the 2nd bottle
3. Fill the 1st bottle with an appropriate amount of sand & water
Add elodea and snails as instructed
4. Insert the bottom of the 2nd bottle into the opening at the top of the first bottle.
5. Uncap the top bottle, and using the funnel, introduce an appropriate amount of soil into the bottle.
6. Add seeds, recap, and place the bottle on the counter near the windows.

Questions:

1. What is a closed system?
2. How is an open system unlike one that is closed?
3. How is the Earth similar to the bottle system?
4. Are there differences between the Earth and the bottle system?
5. Are there exceptions to the Earth being a closed system?

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 2

The Carbon Cycle

Introduction: This activity introduces students to the carbon cycle and the various molecular forms of carbon that are present within the Earth's four systems. For each molecular form of carbon, sugar, carbon dioxide, carbon monoxide, methane, and calcium carbonate, students are to construct a small molecular model from beads as guided by the provided card. Similar to the children's game "Pin the tail on the donkey", students are to affix their completed carbon based molecular model cards at appropriate locations on a supplied carbon cycle background. Particular attention should be given to the biological carbon connections existing between the biosphere and the abiotic components of the Earth: the atmosphere, hydrosphere, and geosphere.

Materials: Carbon Cycle Background from NASA
Carbon Molecular Card Set
Scissors, Glue
Assorted Beads
 Black = Carbon
 White = Hydrogen
 Red = Oxygen
 Blue = Calcium

Directions: 1. Construct the carbon molecular models from the beads using the cards as a guide.
2. Once the models are constructed, place the cards in areas appropriate for each particular molecule.

Questions: 1. What forms of carbon were present within the cycle?

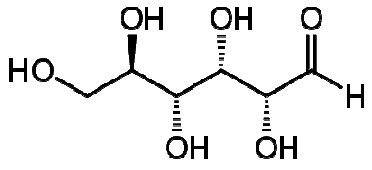
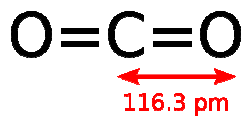
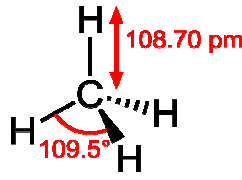
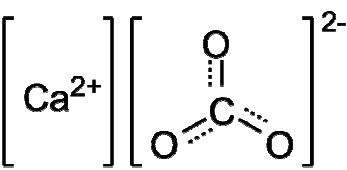
2. What occurred with carbon as it transitioned from one area to another?

3. What contribution to the cycle did plants make?

4. What form(s) of carbon were predominate in the atmosphere?

5. What Earth systems were present in the cycle?

Figure 3. Molecular Model Cards

	Glucose
	Carbon dioxide
	Carbon monoxide
	Methane
	

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 3

The Nitrogen Cycle

Introduction: To examine the nitrogen cycle, and the problems that can be generated through excessive use of fertilizers, students will apply various concentrations of nitrogen containing plant food to pond water samples. Over the span of a week, students will observe the samples for qualitative changes and algal growth.

Materials: 5 100 mL Beakers per group
Pond Water
Plant Food Solution

Directions:

1. Obtain a 100 mL sample of pond water in each of the 5 beakers.
2. Label and arrange the groups beakers along the counter by the windows.
3. Leave one beaker without plant food solution.
4. Among the 4 remaining beakers, add 2, 4, 6, and 8 drops of plant food respectively
5. Observe and note changes among the beakers over the course of the week. On Friday ask the instructor to take a picture of the beaker set.

Questions:

1. Why was the first beaker not given plant food?
2. Were living organisms present in the pond water?
3. What changes did you observe in the beakers?
4. How might the beakers represent the rivers and lakes nearby?
5. What might be some sources of nitrogen runoff locally?

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 4

CO₂ Concentration vs. Temperature

Introduction: This exploration seeks to discern the difference in temperature change experienced by common air when compared with a equal volume of carbon dioxide as both are exposed to solar radiation.

Materials: 2 2L Bottles (with pre-drilled caps)
 2 Digital Thermometers
 2g Carbon dioxide (Dry Ice)

- Directions:**
1. Insert the temperature probe of each digital thermometer through a bottle cap.
 2. Obtain a 2g piece of carbon dioxide from the instructor.
 3. Place the CO₂ into the bottle. Cap both bottles, but do not completely seal the bottles! The bottle caps should remain somewhat loose at all times!
 4. Place the bottles next to each other outside in a spot where there is ample sunlight. Arrange the bottles as best possible to dispel any differences in obtained sunlight.
 5. During the 10 minutes following placement, record the changes in temperature for both bottles a 1 minute intervals.

- Questions:**
1. What is CO₂? How does its GWP compare to other greenhouse gases?
 2. In light of question 1, why is CO₂ of concern as a factor in climate change?
 3. How has the concentration of atmospheric CO₂ changed over time?
 4. How can people lower their contributions to atmospheric CO₂?

Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 5

Soil Types & Plants

Introduction: Using soil-sampling tools students will collect, sift, and analyze a soil sample for their composition in regard to particle size. By using a soil triangle, students will determine the soil type from the percentage of silt, sand, and clay present. Students will then generate soil samples and plant them with seeds, from which they can derive observations focusing on germination, growth, and healthy development of the plants.

Materials: Soil Sample Tube (with bags for each student)
 Soil Sieves
 Soil Triangle Chart
 Dixie Cups
 Bean Seeds

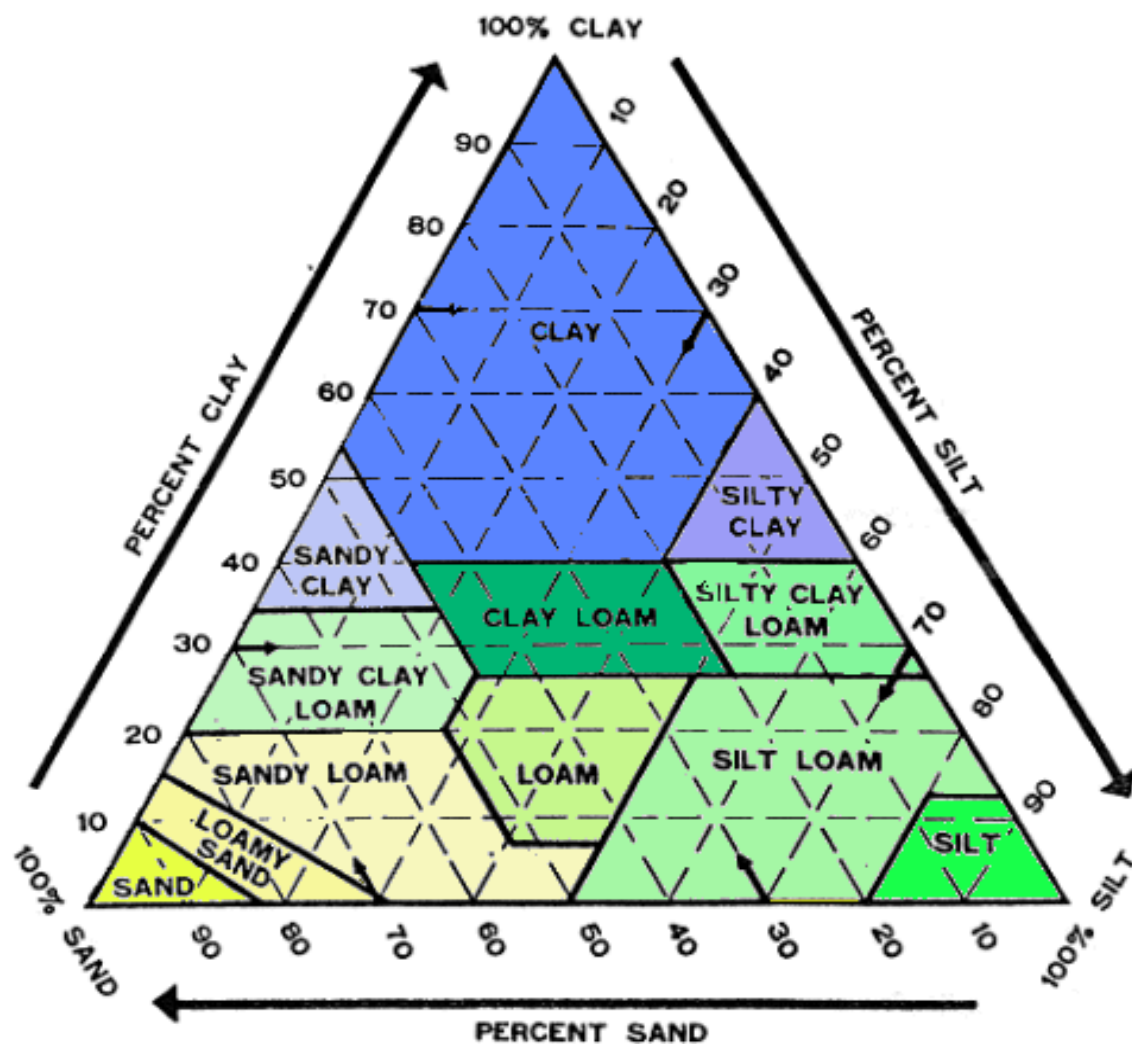
Directions: 1. Obtain a soil core sample as demonstrated in class.
 2. After observing the sample in the tube, empty the sample into a collection bag.
 3. In class, the bagged sample may be sifted through the sieves to determine the amount of sand, silt, and clay present. Record the amount as measured with a balance.
 4. Triangulate on the chart your sample's soil type.
 5. Using the provided silt, sand, and clay, along with the balance, generate a soil sample for one of the soil types (check for assignment).
 6. Plant a seed as instructed, water the sample, and place by the windows for further observation.

Questions: 1. Why do plants need soil?

 2. Of the various soil types, which might be better for plants?

 3. What are the components of soil?

Figure 4.: The Soil Triangle



Earth Science & Biology Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 6

Earth's Magnetic Field

Introduction: The students will construct compasses from assorted materials found within our classroom. Using a magnet, students will magnetize a straightened paperclip and insert it through a Styrofoam ball. Free to rotate within the fluid filled cap, the magnetized paperclip should be observed for magnetic orientation. In conjunction with the pop bottle compass, students will also observe portions of National Geographic's video, [Great Migrations](#), which indicates the possibility that insects and birds may have internal compasses also influenced by Earth's magnetism.

Materials: Pop Bottle Cap
 Paperclip
 Magnet
 Styrofoam ball
 Beaker w/ water

Directions: 1. Straighten the paperclip and stroke the magnet along its length

 2. Continue with the magnet for 50 to 60 strokes

 3. Insert the magnet through the Styrofoam ball.

 4. Fill the inverted bottle cap with water and place the ball/paperclip assembly so it may float on the water's surface.

 5. Observe the paperclip for magnetic orientation.

 6. Gently flick the paperclip to spin it, observe for reorientation

- Questions:
1. How many poles are present within a magnet?
 2. Which magnetic pole is located in the geographic north?
 3. According to the video, which organisms are indicated to possibly detect the Earth's magnetic field?
 4. In the space below draw the domains of unmagnetized and magnetized metal objects:

Earth Science & Biology Connections: Enhancing Earth Science Relevance for
Students through Biological Explorations

Activity 7

Volcanoes & Emerging Life

Introduction: Reading a selected piece, Mountain Transformed, from the May 2010 issue of National Geographic, students will discuss in small groups the devastation and alterations volcanoes impose on the biosphere. In connection with the reading and small group discussions, students will complete a series of guided reading questions related to the article.

Materials: Mountain Transformed article
Guided Question Sheet
Color Pencils

- Directions:
1. Silently and individually read the provided article.
 2. At the end of reading the article, discuss within your group 2-3 examples of destruction and rebound exemplified in the selection.
 3. At the end of the class discussion, complete the guided reading questions.
 4. On the back of the questions, illustrate an example of how other natural events could exhibit disruptions to the biosphere.

Guided question worksheet to follow.

1. What things does Mark Smith remember about Spirit Lake?
2. How much of the mountain avalanched into the lake?
3. What did the lake become? What is the floating mat made of?
4. What was a mystery to Mark before the mountain exploded?
5. What were the trees evidence of?
6. What is the new mystery of Spirit Lake?
7. What was Smith's theory about the fish?
8. Why is it likely that Smith's theory is not correct?
9. How does Bob Lucas think the fish got there?
10. What did genetic testing of the fish reveal?
11. What did Mark's family do at the lake?
12. What would Mark have to do to fish at the lake today?
13. What is the lake at the center of now?
14. Between 2004 to 2008, how high did the plumes of ash and steam rise?
15. What is the blast zone a natural lab to study?
16. What are "biological legacies"?
17. What was the first color that appeared in this world of sterile gray?
18. What do the locals grumble about?
19. What is the "log raft"?
20. What was the first surprise in entering the water?

Connections: Enhancing Earth Science Relevance for Students through Biological Explorations

Activity 8

Transpiration & The Water Cycle

Introduction: After identifying selected trees on campus, students will use large clear plastic bags to cover a selection of leaves. The bags will be left on for a 24-hour period, during which the water released by transpiration will be collected. Students will then compare the amounts of water obtained from the various species of trees with each other.

Materials: Clear Plastic Bags
Twine
DNR Michigan Tree Identification Guide
Digital Balance

Directions:

1. Each group should select and identify 4 unique trees
2. Taking care not to harm the tree, place the bag over a collection of leaves. The mass of the bags should have been recorded prior to going outside.
3. Lightly tie off the bags opening around the tree limb, again not harming the tree.
4. After a 24 hour period, carefully remove the bag from the tree limb. Do not spill the water contained within the bag!
5. Find the mass of the water contained within the bag using a digital balance.

Questions:

1. What benefit(s) might transpiration provide for plants?
2. Where do plants obtain the water they transpire?
3. What other portion of the hydrologic cycle is most like transpiration?

Tree: (common & scientific name)	Mass of H₂O (full bag – empty bag, in g)

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Activity 9

Wetlands & Aquatic Plants

Introduction: Using Wetland Plants of Michigan by Steve Chadde, students will identify a wide variety of plants found within Ann Arbor's Gallup Park along the Huron River. Digital photos of the plants will be taken during the outing, with small groups of students sharing selected botanical photos with the class upon our return.

Materials: 8 Wetland Plants of Michigan by Steve Chadde
Digital Cameras (Students may appropriately use camera phones)

Directions: 1. Each small student group should select 5 different plants they wish to record.
2. For each plant, identify both its common and scientific name using the guide.

Questions:

Plant Common Name	Plant Scientific Name	Description & pg. #

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Activity 10

Aquifers

Introduction: Constructing an aquifer models from 60 milliliter syringes, sand, and gravel, students will explore the concepts of porosity and permeability.

Materials: 60 mL syringe
Ring Stand
Clamp
“Aquifer” Container (Large Bin beneath Ring Stand)
Sand & Gravel
100 mL Graduated Cylinder

Directions:

1. Set the ring stand and clamp within the “aquifer” bin to minimize water loss
2. Place the syringe in the clamp on the stand.
3. Fill the syringe with 25 mL of gravel, followed by 25 mL of sand.
4. For porosity, start with the Graduated Cylinder filled to 100 mL. Cap the end of the syringe and slowly fill it with water until the water is even with the sand at the 50 mL mark.
5. Record the volume of water used to fill the syringe to the 50 mL mark
6. For permeability, uncap the syringe, and using a filled 100 mL graduated cylinder pour the water through the syringe while timing the time it takes for it to pass through this system. This will take the effort of both lab partners, one to time and another to pour!
7. Repeat the permeability portion until three trials have been conducted.

Questions:

1. What is the difference between discharge and recharge?
2. What in the model used is an example of an input?
3. Why is groundwater of importance in Michigan if we have so many lakes?

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Activity 11

Lakes & Michigan Fishes

Introduction: Students will use Dave Bosanko's Fish of Michigan Field Guide in order to identify a variety of preserved fish specimens native to Michigan. In addition, students will use the internet to uncover information in regard to Michigan's fish hatcheries.

Materials: 8 Wetland Plants of Michigan by Steve Chadde
Preserved Fish Specimens (from Biology or Kensington Metropark photos)
Fish of the Great Lakes Chart (from Wisconsin Seagrant:
<http://www.seagrant.wisc.edu/greatlakesfish/>)

Directions: 1. Each small student group should select 5 different fish they wish to record.
2. For each fish, identify both its common and scientific name using the guide.

Questions:

Fish Common Name	Fish Scientific Name	Description & pg. #

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Activity 12

Earth's History & Timelines

Introduction: Students, working in small collaborative groups, will produce timelines of Earth's history, highlighting as necessitated by Michigan's state standards the occurrences of the formation of the Earth, the formation of an oxygen atmosphere, the rise of life, the Cretaceous-Tertiary (K-T) and Permian extinctions, as well as the Pleistocene ice age. Employing their course textbook as a source, students generate the timeline to scale on 5 meter strips of adding machine paper rolls.

Materials: Color Pencils
5 m strips of Adding Machine Paper
Meter sticks
Rulers
Student Text (Holt Earth Science)

Directions: Using the supplied materials, create a timeline of the Earth.
The timeline should incorporate color, be aesthetically pleasing, and highlight the events in the introduction.

In addition to the text, you may use the URL below, but keep in mind the scale is based on a 1 m timeline, not a timeline of 5 m.

http://www.beavercreek.k12.oh.us/4036209511325677/lib/4036209511325677/Timeline_activity.pdf

Questions:

1. Approximately how old is the Earth?
2. When did humans first appear within the timeline?
3. At what stage did life first appear?

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Activity 13

Carbon Dating

Introduction: Using bingo chips as models of atomic decay, students will explore the concept of radiometric decay and its use as a tool for measuring the passage of geological time. The chips, within a container, are shaken and placed on a table. Those chips that indicated decay are tabulated and removed, with the process cycling for seven rounds. Students will utilize graphing skills, and work in small groups to determine the mathematical relationships involved in the decay and timing correlation.

Materials: Bingo Chips (Borrowed! Please keep chips on table at all times!)
Chips Container
Graph Paper

Directions: Beginning with all of the chips in the container, give the container a shake and gently place the chips on the table. Return all of the chips that are “up” (you can read the word up) to the container. For those chips that read “PU” (but with a backwards P), count them, and place them in a decay pile.

Continue the trials until no more chips are left to shake, or seven rounds have occurred, whichever comes first.

Graph the instances of decay. On the X-Axis indicate the # of trials. On the Y-Axis indicate the # of decayed chips.

Questions:

1. Between instances of decay, what pattern developed concerning the decaying chips?
2. Why is C-14 only useful in dating once living things?
3. Through what process(es) do living things obtain carbon-14?
4. What other forms (or elements) are used by geologists in radiometric dating?

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Activity 14

Index Fossils

Introduction: Using plastic models of fossils, students will identify each fossil and work in small groups to determine the ages of rock strata present on a backdrop of sedimentary layers from which the fossils were obtained. The students will also explore a variety of extinct forms of life representative of selected periods from Earth's history.

Materials: 8 Fossil Models Kit (Carolina: GEO8408)
8 GEO8408 Worksheet Packet (1 per group)

Directions: 1. Sign out a Fossil Kit and Guide
2. For each completed section, check in with the instructor and obtain a completion stamp.

There are 5 exercises to complete:

Fossil ID	Fossil Molds	Symmetry	Fossil Cast	Guide Fossil Correlation

Question:

List the characteristics of Index Fossils below:

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Activity 15

Sunprints

Introduction: Uniting the endeavors of Science and Art, students will create sunprints, or cyanotypes, of flowers, grasses, leaves, and other materials of interest. Students will dip sheets of 8 ½ by 11-inch paper into a pan containing a combination of aqueous solutions, one part potassium ferricyanide to one part ferric ammonium citrate (green).

Materials: Paper (Photo or Heavier Paper where available)
Cyanotype solutions as per Alternative Photography,
(www.alternativephotography.com)
Newspaper for blotting and overnight storage.
Dipping Tray
Tongs

Directions: Use Protective Eyewear and Gloves when dipping your cyanotype sheet!

1. Obtain an 8 ½ by 11” sheet of paper near the tray, initial it and indicate your class hour.
2. Dip the sheet in the tray. As you remove it, let it drip into the tray for a moment.
3. Place your sheet in your hour’s newspaper for overnight storage.
4. Let’s make some prints! Obtain your sheet, and remove a 1” strip.
5. Place your sheet in a sunny location, with flowers, grasses, leaves, or other natural materials on top. Rocks can help weigh down the corners if windy!
6. Place the 1” strip in the provided book for your group. Pull out 1” segments of the strip at 2 minute intervals.
7. Bring in your completed print. Take it home, give it a gentle rinse, and let it dry.

Questions:

1. How did your print turn out?
2. What occurred with the 1” strip? How did the different exposure times affect it?

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Activity 16

Rivers & Tree Distribution

Introduction: Students will attempt to discern a relationship between tree distribution and surface water, in particular the Huron River. Students will plot the location of identified trees. Using provided handheld GPS units, the location and species of 5 different trees will be collected by small collaborative groups. The collected data was then uploaded for digital mapping from which the collective tree locations could be observed.

Materials: 5 Garmin GPS Units
Desktop with mapping software.

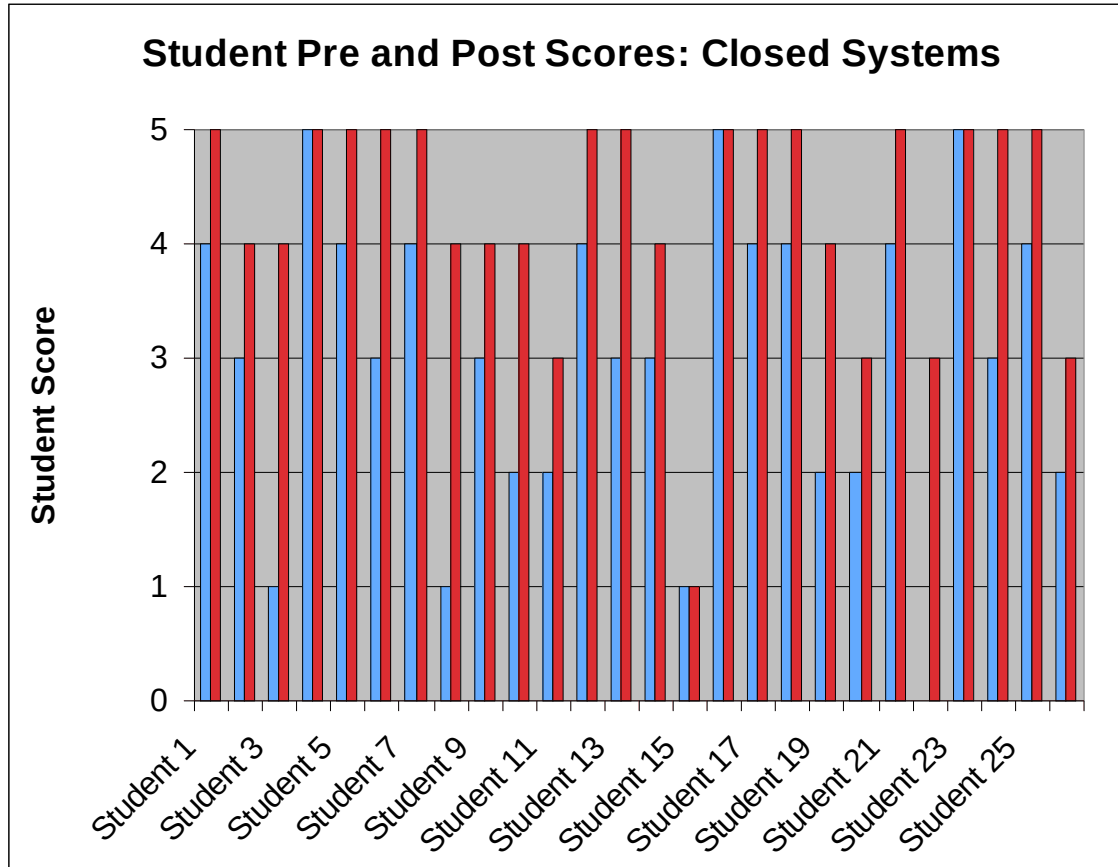
Directions: For 5 unique trees, your group should record its position (in UTM), species, and common name.

Location (in UTM)	Tree Scientific Name	Tree Common Name

Remember to upload your group's data to the map!

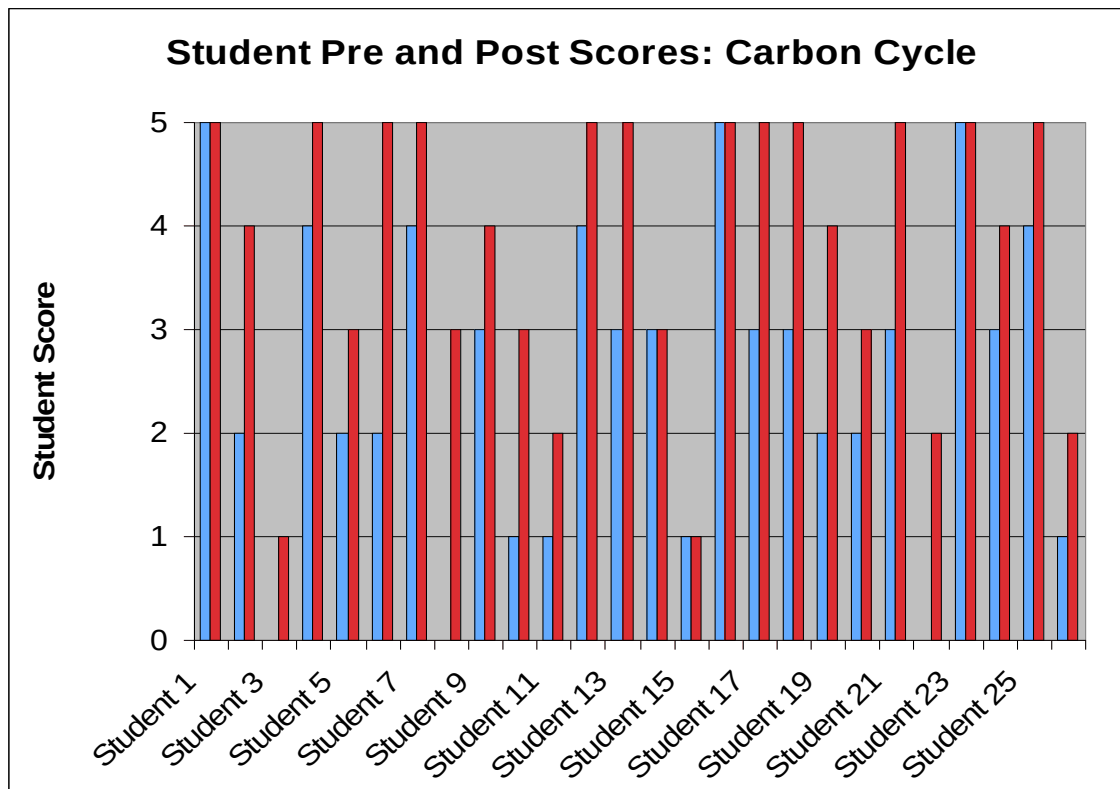
APPENDIX IV

Figure 5.: Student Pre and Post Scores: Closed Systems



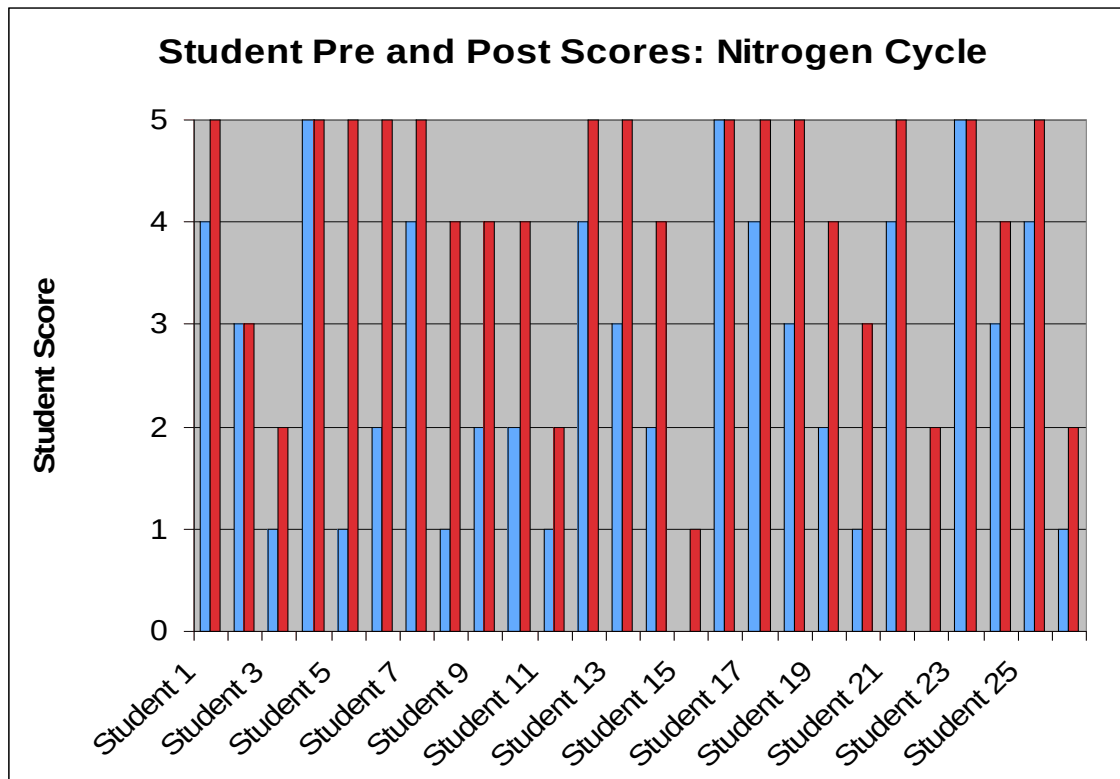
For the closed systems activity the mean gain in score ($M=1.27$, $SD =0.874$, $N= 26$) was significantly greater than zero, where $t = -7.401$, $P = 0.000$, providing evidence that the activity was effective in disseminating requisite knowledge regarding closed systems and demonstrating a connection between this Earth Science concept and Biology. The data from this assessment displayed a 95% confidence level of 0.353.

Figure 6.: Student Pre and Post Scores: Carbon Cycle



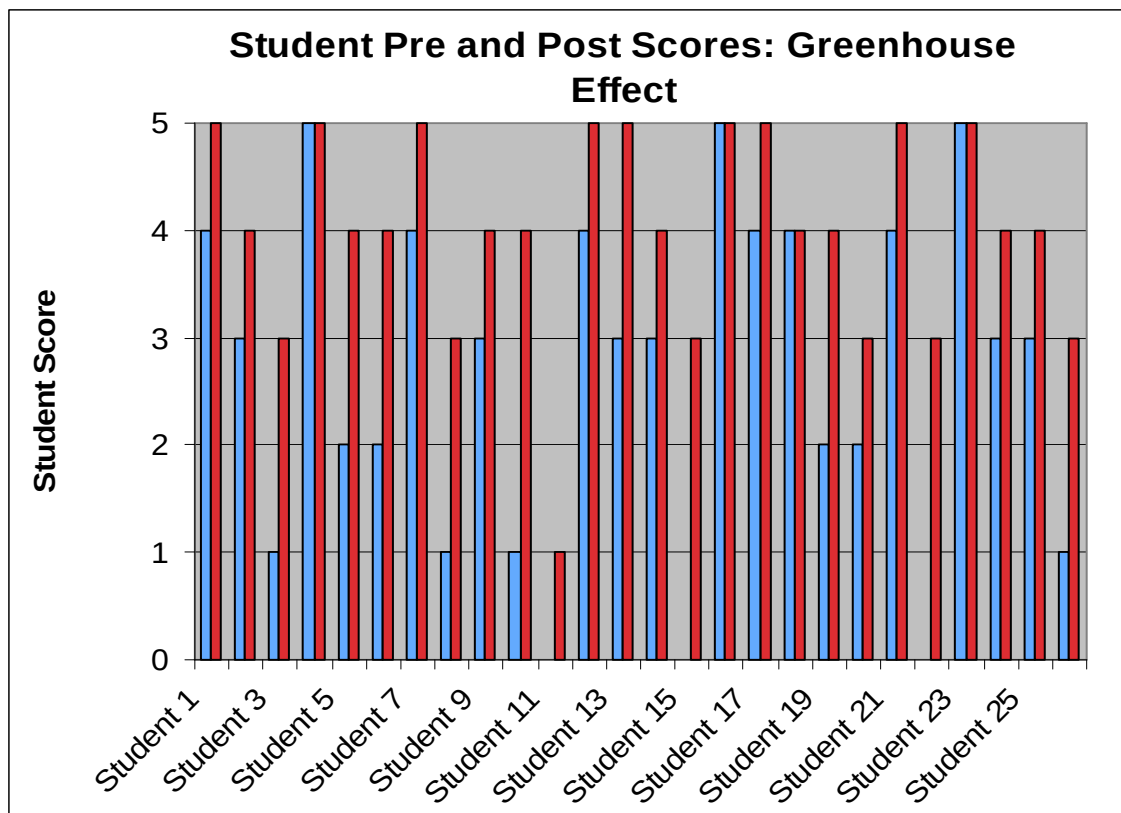
The Carbon Cycle portion of the study exhibited a mean score gain from pre-test (2.54) to post test (3.81) greater than zero ($M=1.27$, $SD =0.874$, $N= 26$), indicating enhanced student understanding of the role the carbon cycle plays within the biosphere. A 95% confidence level of 0.353 was indicated.

Figure 7.: Student Pre and Post Scores: Nitrogen Cycle



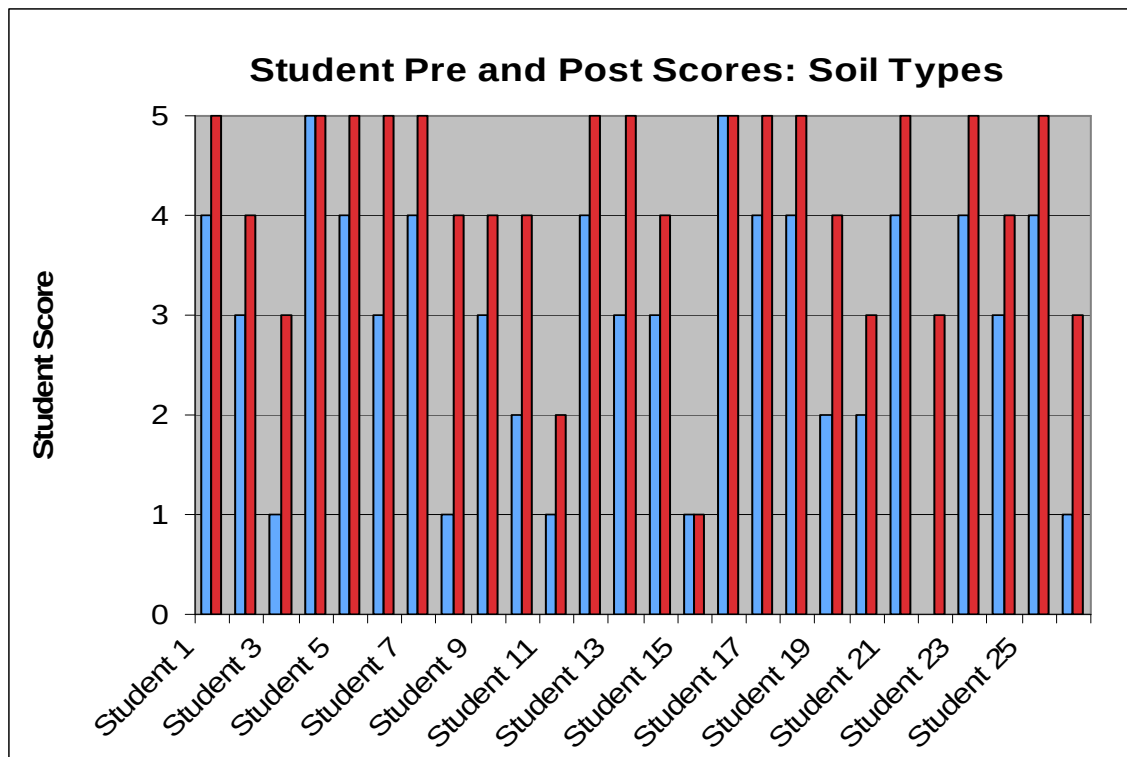
For this portion mean gains considerably above zero were realized ($M=1.42$, $SD = 0.986$, $N= 26$).

Figure 8.: Student Pre and Post Scores: Greenhouse Effect



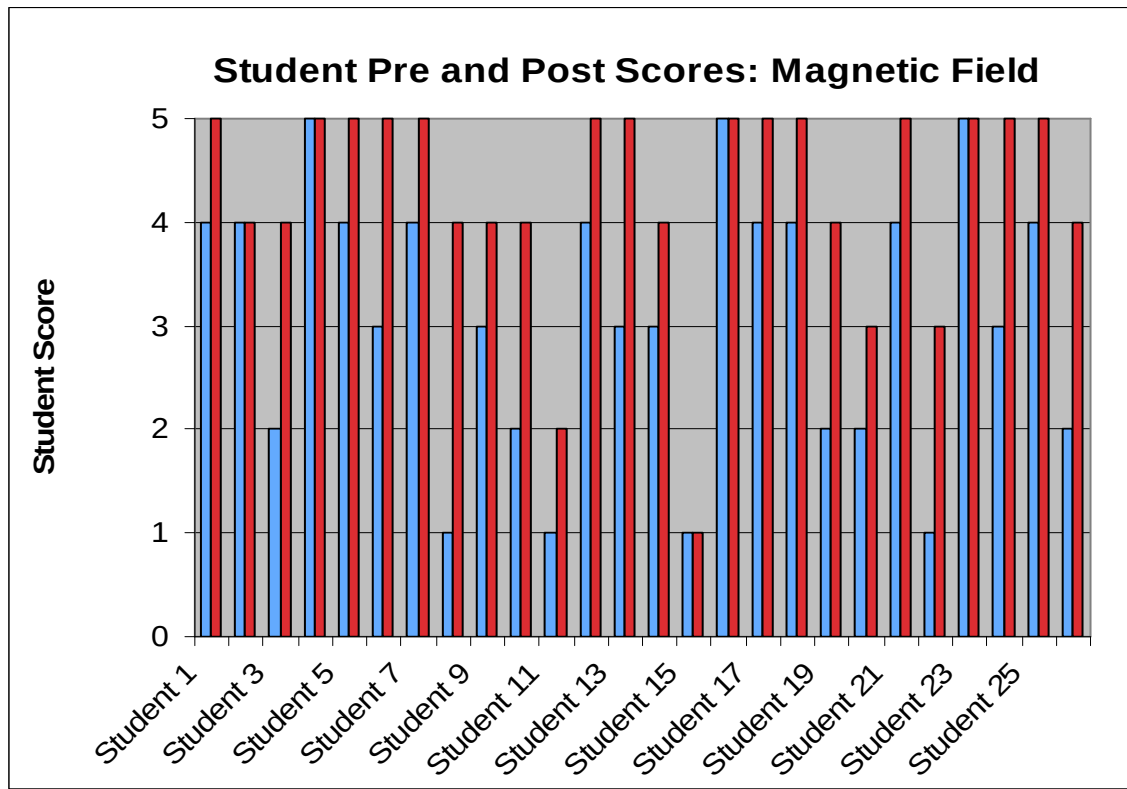
By virtue of a significant rise in mean score ($M=1.35$, $SD =0.892$, $N= 26$), student consideration of greenhouse gases as an atmospheric environmental factor was established with a 95% confidence level of 0.360.

Figure 9.: Student Pre and Post Scores: Soil Types



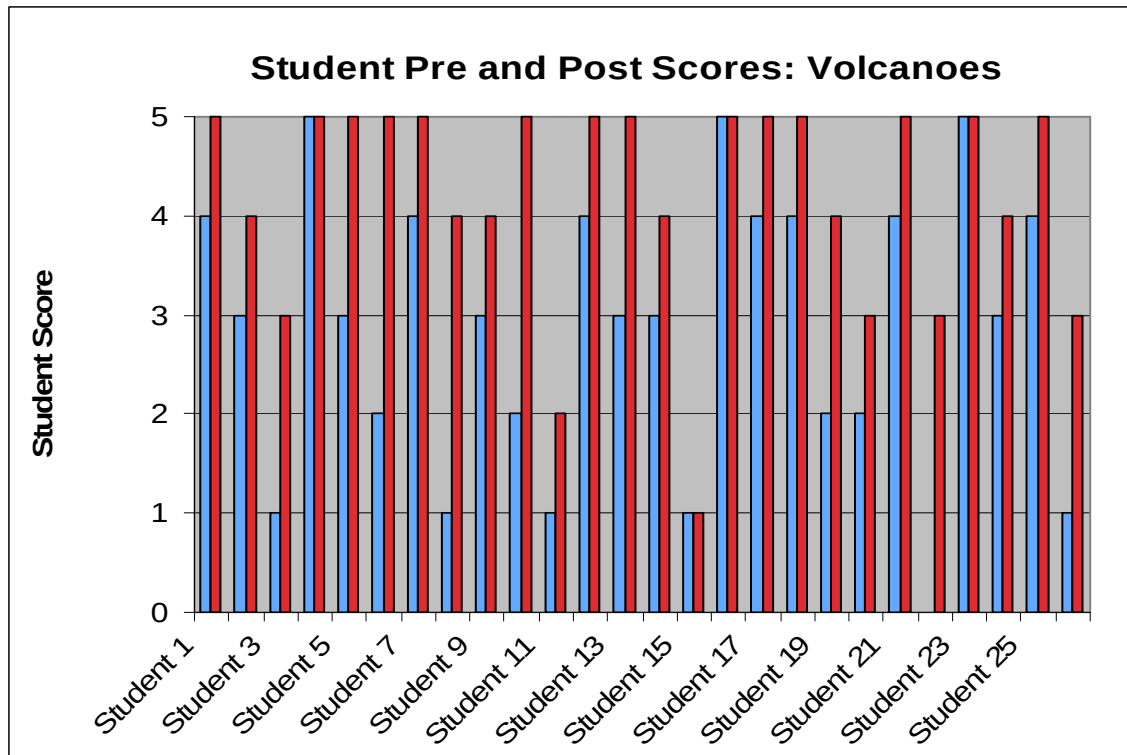
The mean average gain presented within this section ($M=1.27$, $SD =0.778$, $N= 26$), combined with a 95% confidence level of 0.314, suggest deeper student understanding of soil types and formation.

Figure 10.: Student Pre and Post Scores: Magnetic Field



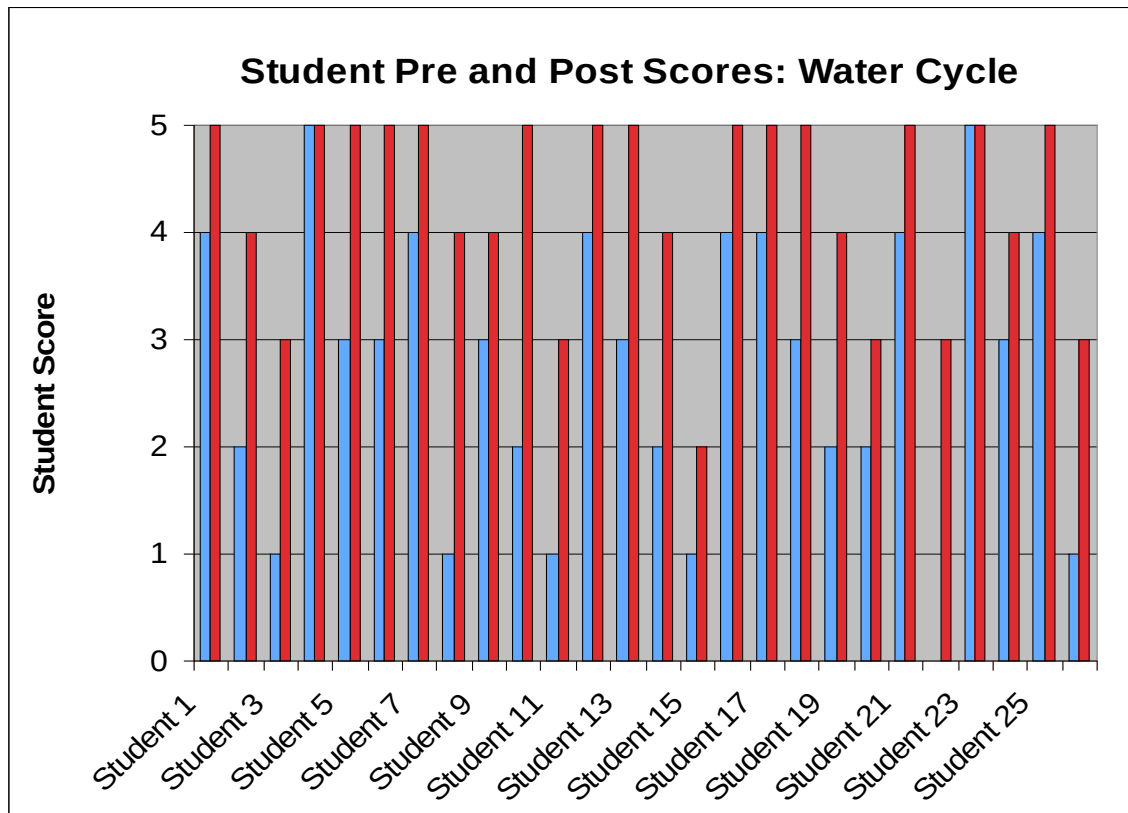
Despite an instance of regression, the student mean score for the section still presented distinct gain ($M=1.19$, $SD = 0.801$, $N= 26$) with a 95% confidence level of 0.324.

Figure 11.: Student Pre and Post Scores: Volcanoes



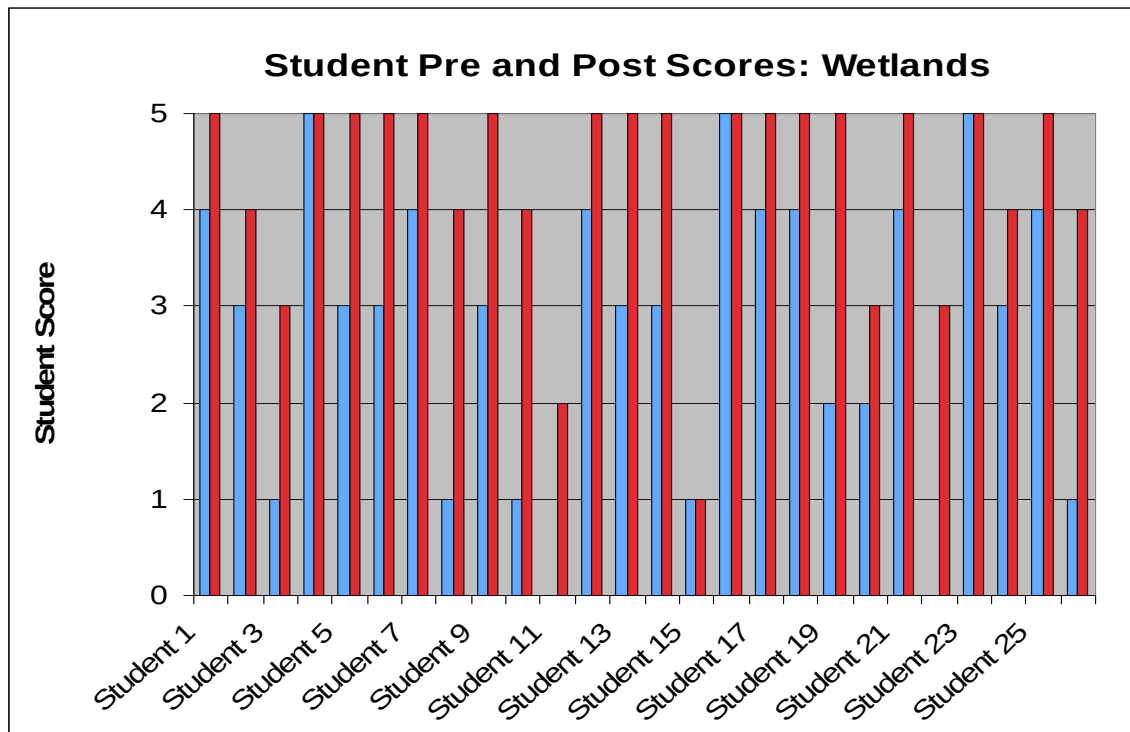
Reflecting achievement in grasping the damage volcanoes can inflict on the biosphere, students displayed increased mean scores ($M=1.35$, $SD =0.936$, $N= 26$) while learning about Mt. St. Helens and its ecological recovery. The pre- and post-test data for this activity displayed a 95% confidence level of 0.378.

Figure 12.: Student Pre and Post Scores: Water Cycle



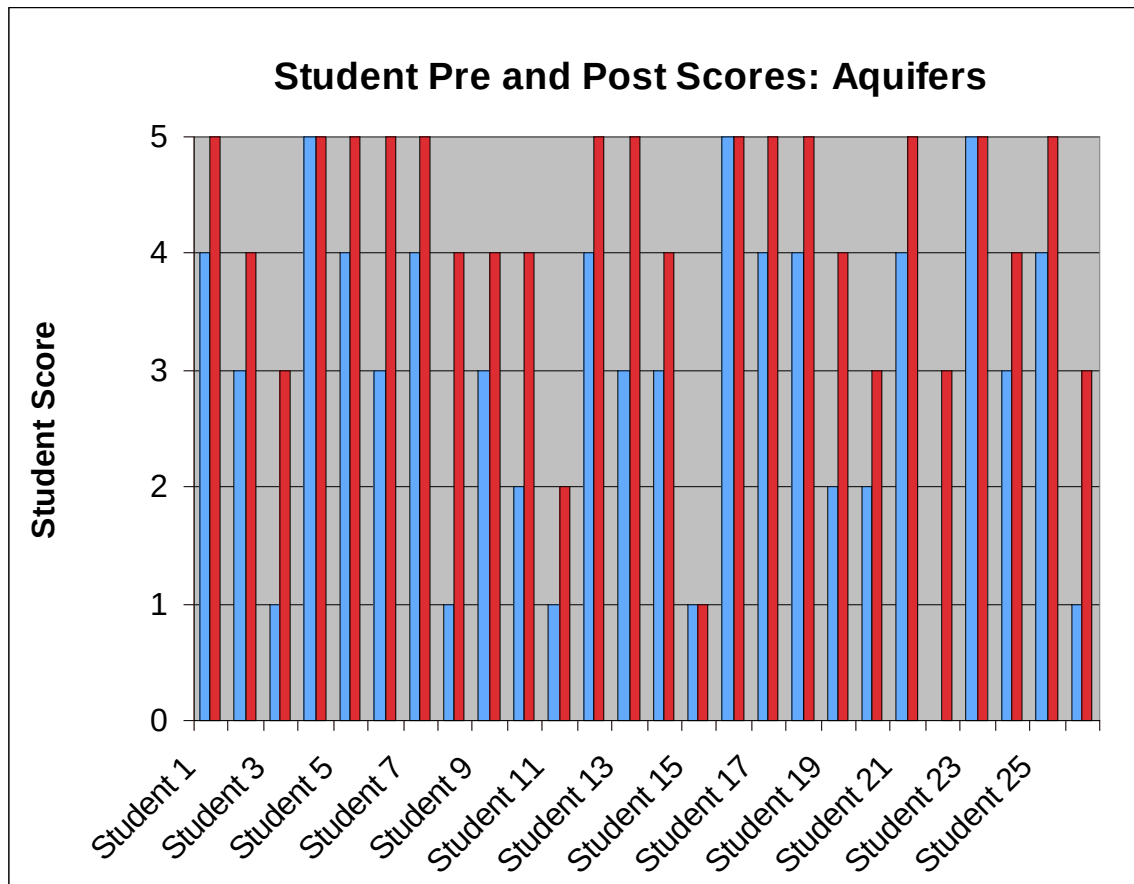
The overall gains in mean scores ($M=1.54$, $SD = 0.811$, $N= 26$) and 95% confidence level of 0.328 indicate the activity reinforced student familiarity with the hydrologic cycle and their appreciation of its connection to the biosphere.

Figure 13.: Student Pre and Post Scores: Wetlands



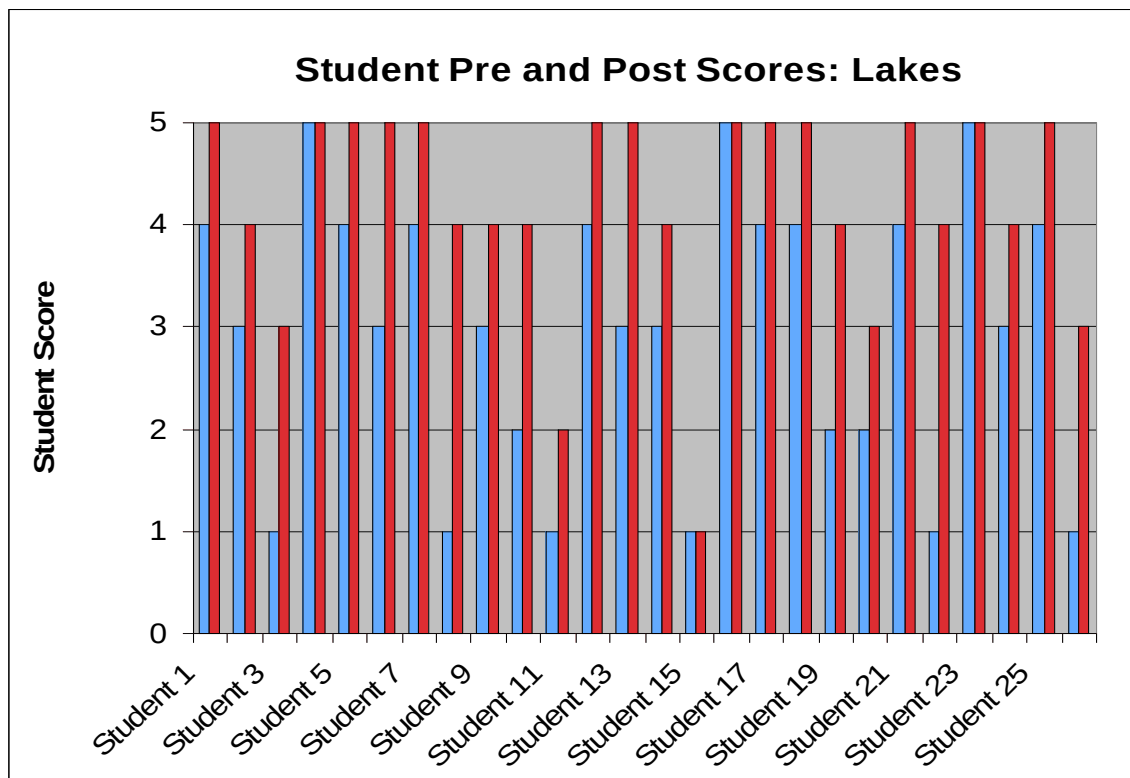
This portion of the study displayed an increase in mean scores ($M=1.50$, $SD =0.990$, $N=26$) with a 95% confidence level of 0.400. These increases show enhanced student awareness for the connections between our wetland areas and the biosphere.

Figure 14.: Student Pre and Post Scores: Aquifers



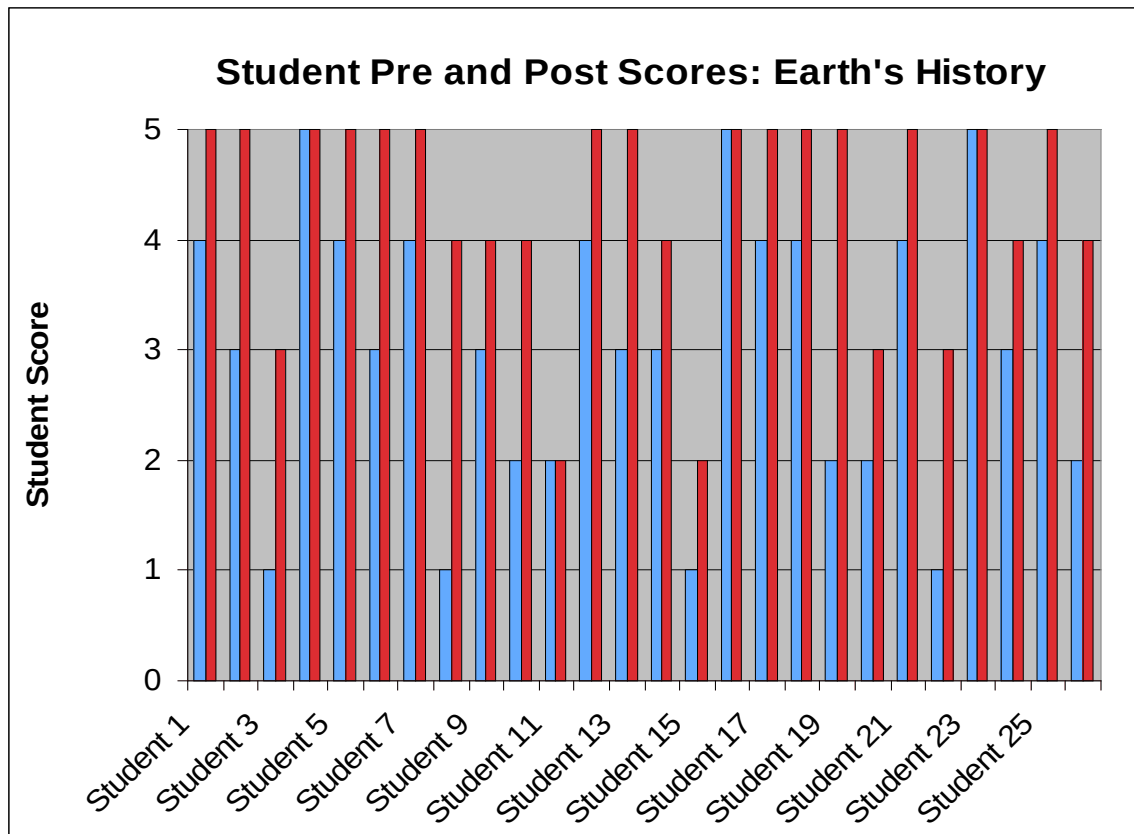
Learning both the concepts of porosity and permeability, students demonstrated significant gains in understanding groundwater flow as indicated by their mean score augmentation ($M=1.23$, $SD = 0.815$, $N= 26$) and 95% confidence level of 0.329.

Figure 15.: Student Pre and Post Scores: Lakes



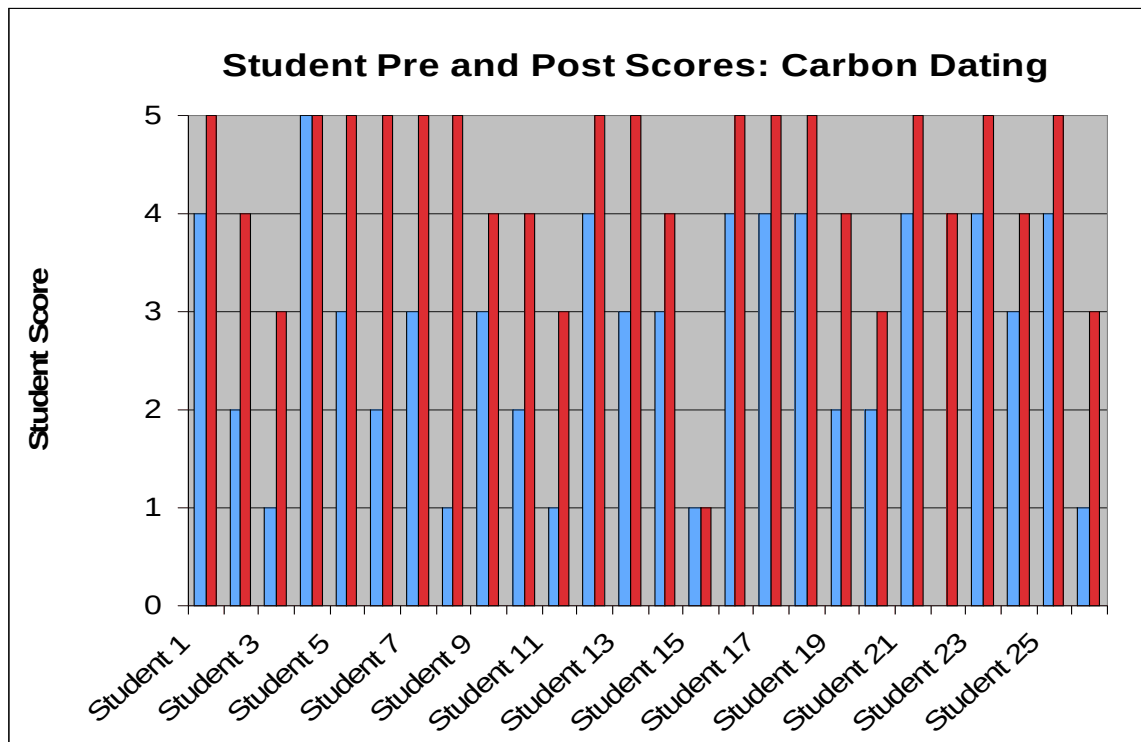
The Lakes section of the study displayed a mean score gain from pre-test (2.96) to post test (4.19) greater than zero ($M=1.23$, $SD=0.815$, $N=26$), indicating enhanced student awareness of the Great Lakes as a Michigan natural resource, and a biologically valuable portion of the hydrosphere. A 95% confidence level of 0.329 was noted for this activity.

Figure 16.: Student Pre and Post Scores: Earth's History



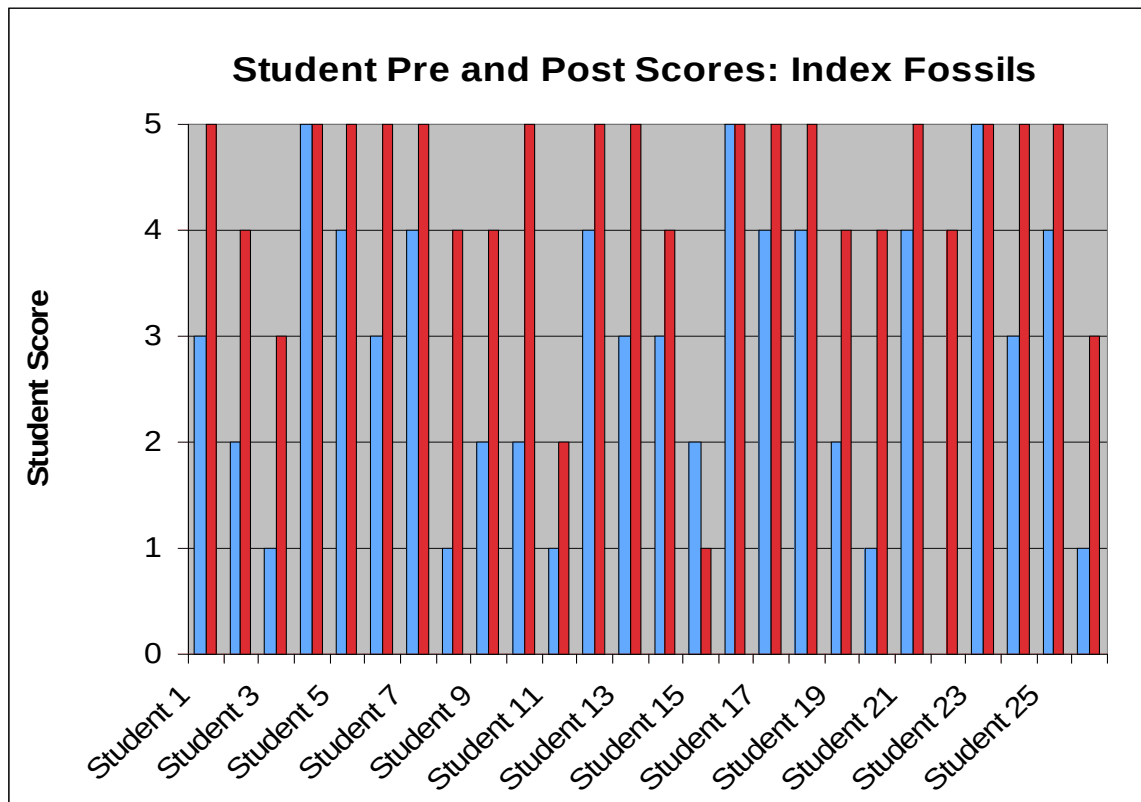
For the Earth's History activity, the mean gain in score ($M=1.27$, $SD = 0.827$, $N= 26$) was significantly greater than zero, where $t = -7.822$, $P = 0.000$, establishing that the activity was helpful in imparting an understanding about Earth's immense past and revealing the connections between both the Earth and biology over time. The data from this assessment indicated a 95% confidence level of 0.334.

Figure 17.: Student Pre and Post Scores: Carbon Dating



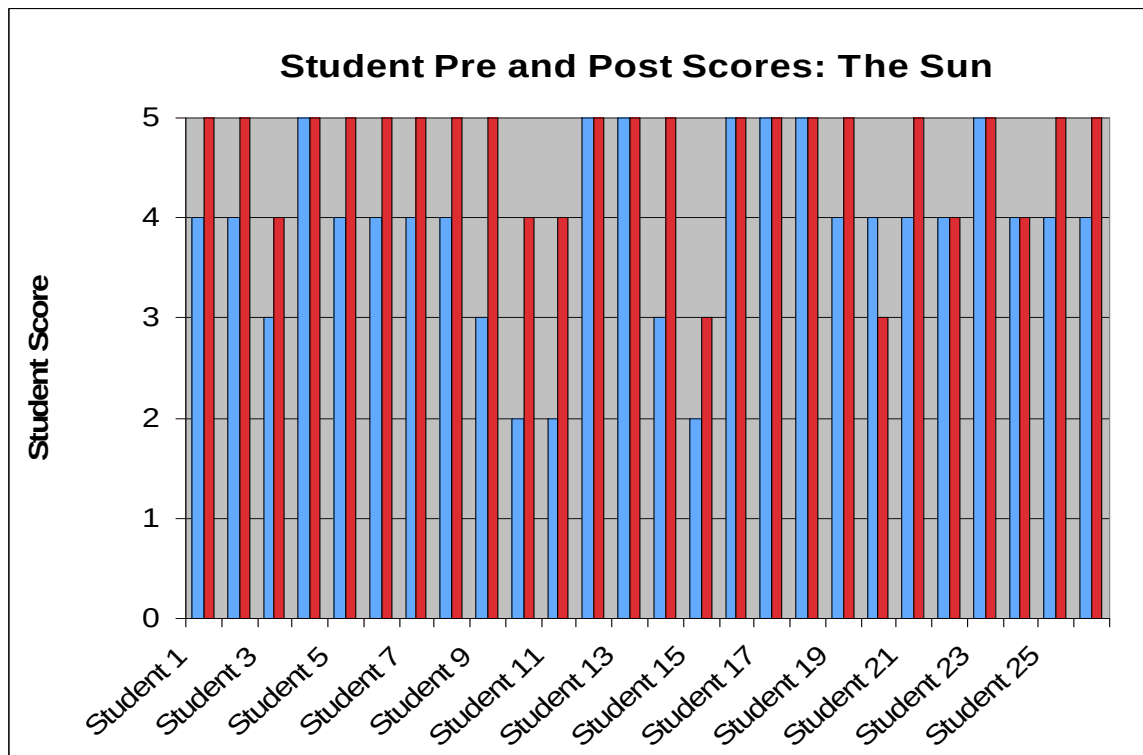
For this section mean gains significantly above zero ($M=1.58$, $SD=0.987$, $N=26$) were evident, where $t=-8.148$ and $P=0.000$.

Figure 18.: Student Pre and Post Scores: Index Fossils



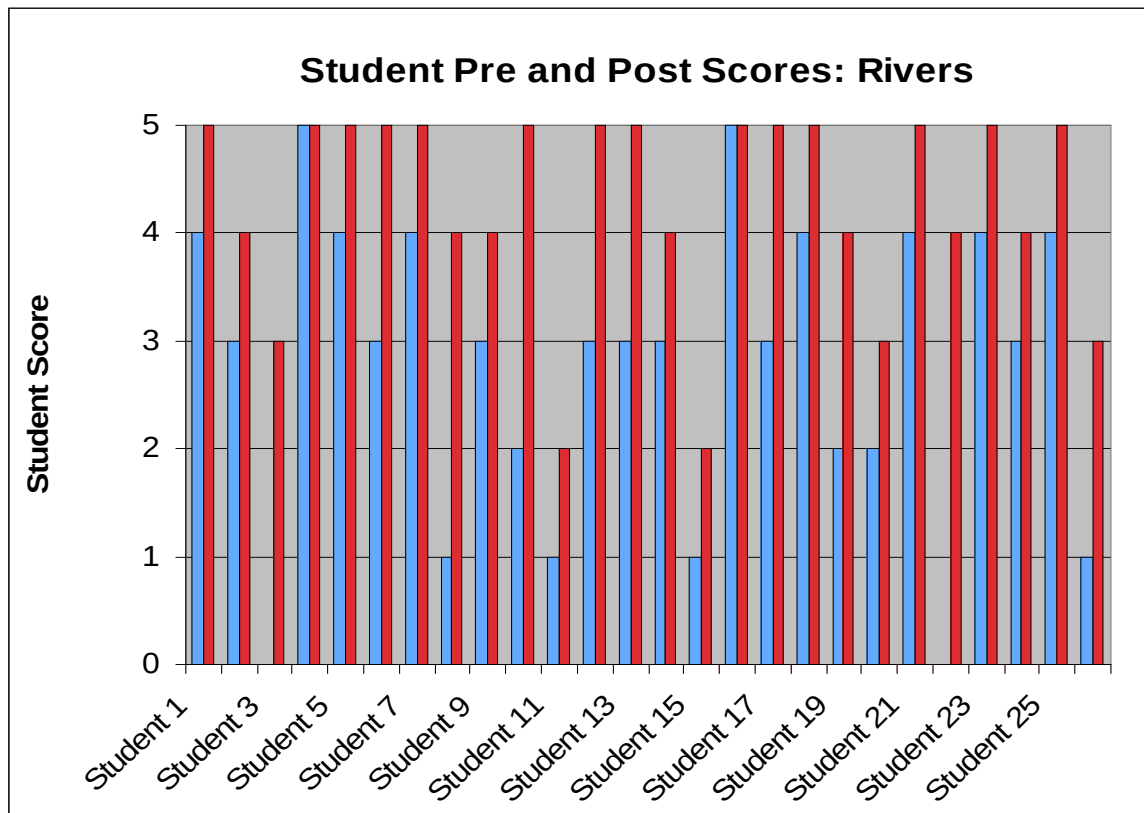
The students' gains in mean scores ($M=1.50$, $SD = 1.105$, $N= 26$) and 95% confidence level of 0.446 indicate the activity enhanced student awareness of fossils, remnants of the biosphere, and the correlation they share with the rock record, an account of the geosphere.

Figure 19.: Student Pre and Post Scores: The Sun



The Sun portion of the study exhibited a notable increase in mean scores ($M=0.73$, $SD=0.990$, $N=26$) with specific student gains in understanding the Sun's role as the Earth's primary source of energy. With a 95% confidence level of 0.314, where $t=-4.792$ and $P=0.000$, these gains display improved student awareness for the connections between the Sun and Earth's systems.

Figure 20.: Student Pre and Post Scores: Rivers



Through a considerable rise in mean score ($M=1.50$, $SD =0.949$, $N= 26$), along with a 95% confidence level of 0.383, student knowledge of rivers, their characteristics, and the hydrologic contribution they provide to the biosphere was demonstrated.

APPENDIX V

Relevant Michigan Earth Science High School Content Expectations by Activity

Closed Systems:

E2.1A - Explain why the Earth is essentially a closed system in terms of matter.

E2.1B - Analyze the interactions between the major systems (geosphere, atmosphere, hydrosphere, biosphere) that make up the Earth.

E2.1C - Explain, using specific examples, how a change in one system affects other Earth systems.

The Carbon Cycle:

E2.3A - Explain how carbon exists in different forms such as limestone (rock), carbon dioxide (gas), carbonic acid (water), and animals (life) within Earth systems and how those forms can be beneficial or harmful to humans.

E2.3d - Explain how carbon moves through the Earth system (including the geosphere) and how it may benefit (e.g., improve soils for agriculture) or harm (e.g., act as a pollutant) society.

E2.2f - Explain how elements exist in different compounds and states as they move from one reservoir to another.

The Nitrogen Cycle:

E2.3b - Explain why small amounts of some chemical forms may be beneficial for life but are poisonous in large quantities (e.g., dead zone in the Gulf of Mexico, Lake Nyos in Africa, fluoride in drinking water).

E2.3c - Explain how the nitrogen cycle is part of the Earth system.

Greenhouse Effect:

E5.4A - Explain the natural mechanism of the greenhouse effect including comparisons of the major greenhouse gases (water vapor, carbon dioxide, methane, nitrous oxide, and ozone).

E5.4C - Analyze the empirical relationship between the emissions of carbon dioxide, atmospheric carbon dioxide levels and the average global temperature over the past 150 years.

E5.4g - Compare and contrast the heat-trapping mechanisms of the major greenhouse gases resulting from emissions (carbon dioxide, methane, nitrous oxide, fluorocarbons) as well as their abundance and heat-trapping capacity.

E5.r4j - Predict the global temperature increase by 2100, given data on the annual trends of CO₂ concentration increase. (*recommended*)

Soil Types & Formation:

E3.p1B - Explain how physical and chemical weathering leads to erosion and the formation of soils and sediments. (*prerequisite*)

Earth's Magnetic Field:

E3.2A - Describe the interior of the Earth (in terms of crust, mantle, and inner and outer cores) and where the magnetic field of the Earth is generated.

Volcanoes:

E3.4C - Describe the effects of earthquakes and volcanic eruptions on humans.

E3.4e - Explain how volcanoes change the atmosphere, hydrosphere, and other Earth systems.

Water Cycle:

E4.p1A - Describe that the water cycle includes evaporation, transpiration, condensation, precipitation, infiltration, surface runoff, groundwater, and absorption. (*prerequisite*)

Wetlands:

E4.p1D - Explain the types, process, and beneficial functions of wetlands.

Aquifers:

E4.1B - Explain the features and processes of groundwater systems and how the sustainability of North American aquifers has changed in recent history (e.g., the past 100 years) qualitatively using the concepts of recharge, residence time, inputs, and outputs.

E4.1C - Explain how water quality in both groundwater and surface systems is impacted by land use decisions.

Lakes:

E4.1 - Fresh water moves over time between the atmosphere, hydrosphere (surface water, wetlands, rivers, and glaciers), and geosphere (groundwater). Water resources are both critical to and greatly impacted by humans. Changes in water systems will impact quality, quantity, and movement of water. Natural surface water processes shape the landscape everywhere and are affected by human land use decisions.

E4.p3C - Explain the formation of the Great Lakes. (*prerequisite*)

Earth's History:

E5.3C - Relate major events in the history of the Earth to the geologic time scale, including formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.

Carbon Dating:

E5.3B - Describe the process of radioactive decay and explain how radioactive elements are used to date the rocks that contain them.

E5.3f - Explain why C-14 can be used to date a 40,000 year old tree but U-Pb cannot.

Index Fossils:

E5.3D - Describe how index fossils can be used to determine time sequence.

E5.3x - Early methods of determining geologic time, such as the use of index fossils and stratigraphic principles, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it possible to determine how many years ago a given mineral or rock formed. Different kinds of radiometric dating techniques exist. Technique selection depends on the composition of the material to be dated, the age of the material, and the type of geologic event that affected the material.

The Sun:

E5.2 - Stars, including the Sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. Solar energy is responsible for life processes and weather as well as phenomena on Earth. These and other processes in stars have led to the formation of all the other chemical elements.

E2.2A - Describe the Earth's principal sources of internal and external energy (e.g., radioactive decay, gravity, solar energy).

E2.2B - Identify differences in the origin and use of renewable (e.g., solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.

Rivers:

E4.1 - Fresh water moves over time between the atmosphere, hydrosphere (surface water, wetlands, rivers, and glaciers), and geosphere (groundwater). Water resources are both critical to and greatly impacted by humans. Changes in water systems will impact quality, quantity, and movement of water. Natural surface water processes shape the landscape everywhere and are affected by human land use decisions.

E4.p1C - Describe the river and stream types, features, and process including cycles of flooding, erosion, and deposition as they occur naturally and as they are impacted by land use decisions.
(prerequisite)

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