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Paleoecology: An Untapped Resource for Teaching Environmental Change

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Global warming and climate change have become hot topics that incite debate, inspire scientific research, and influence international policy. However, the scientific research that provides the past climate and environmental information upon which contemporary environmental change is measured, receives little attention in high school curriculum. Paleoecology, the study of ancient ecosystems, provides a unifying theme for teaching multiple high school science curriculum concepts involving global environmental change. As a teaching tool, paleoecology establishes a framework linking concepts such as geologic time, climate change, adaptation, survival, extinction, human impact and ecological interactions that are often taught separately. This article provides a brief overview of how the science of paleoecology can be introduced to students and incorporated into the curriculum through simple activities. The activities outlined here include using elevation maps or Gazetteers to investigate potential sites where marine fossils may be found far from the ocean, using multiple biological proxies to measure climate change, and creating models to demonstrate the impact of sea level rise on coastal ecosystems. These activities provide numerous opportunities for the students to discuss the scientific research associated with climate change, the economic impacts of changing climate, and how science may influence policy regarding climate change mitigation.

Key Words: climate change, curriculum, geologic time, global environmental change, paleoecology, proxy data, teaching

Why Included Paleoecology in the Curriculum?

Climate change and global warming have become mainstream topics in many science classrooms, although, the scientific data for current concerns regarding global climate change are not typically addressed in the curriculum. By applying paleoecology as a teaching tool, teachers can help students overcome the misconception that Earth's climate is constant by providing examples of authentic data from a variety of sources found in paleoecological records. By

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understanding the impact past climate fluctuations have inflicted on ancient ecosystems students can create models and test hypotheses about potential impacts of future climatic change.

What is Paleoecology?

The study of ancient environments is known as paleoecology. Because it is impossible to travel back in time and experience Earth's ancient environments, scientists use indicators of past environmental change. Naturally occurring indicators of environmental variability that are used to reconstruct ancient ecosystems are called proxies. Proxy data provide scientists with indirect evidence of environmental change for periods prior to instrumental recordings. The scientists who study these ancient environments are known as paleoecologists.

Paleoecologists often use climate proxies to study the effect of climate change on ancient plant and animals communities. For example, analyzing sediment cores (Figure 1) provides a mechanism for obtaining biological information about what grew in or around a lake or ocean basin at different times in the past. Biological proxies commonly used by paleoecologists include fossilized foraminifera (single-celled marine protozoa with a shell) found in marine sediments, fossilized ear-bones of fish (otoliths), and fossil pollen. All of these proxies are very small and need to be identified using a microscope. Analyzing the chemical composition of sediment cores can also reveal signals of climate change. Additional records of climate variability can be obtained through density and chemical analysis of tropical coral skeletons or the chemical analysis of tiny air bubbles trapped in frozen glaciers and ice caps on mountains.

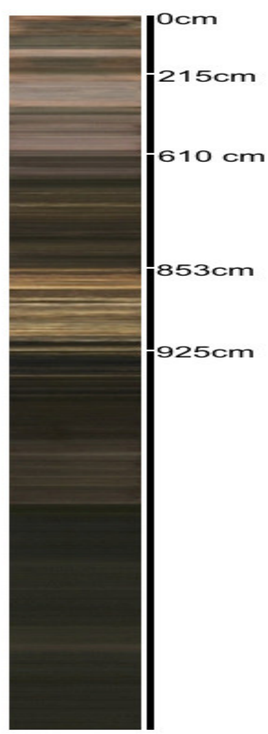

Figure 1. Sediment core collected from Lake Pacucha, Andahuaylas, Peru. Photo by Bryan Va lencia, Florida Institute of Technology.

Climate proxies are often the only indicator of Earth's climatic history.

Climate is not Constant

A common misconception by many students is that climate has not changed significantly throughout Earth's history. Of course, many students have likely seen movies such as Ice Age that provides a narrow view into potential environmental changes during Earth's prehistoric past. The challenge is to bring vague scientific concepts, such as climate change, presented through mainstream media, into the classroom. Through this guided lesson, students answered lower-to higher-level questions furthering their understanding of past climate change. This type of questioning is essential to inquiry based learning (McLaughlin, 2006).

Activity 1: Fossil Finds

Objectives: The students will be able to:

- explain why marine fossils can be found in sediments taken from areas far away from the ocean;
- use state Gazetteers to develop hypotheses about possible locations where marine fossils may be found in Florida.

The *Fossil Finds* activity began when the students entered the room and saw a replica sediment core encased in Plexiglas displayed at the front of the classroom. Exhibited with the replica sediment core were authentic fossils from mammoth, camelid, equid, manatee, shark, and fabricated fossilized mammoth dung that corresponded with the appropriate epochs represented in the replica sediment core (Miocene, Pliocene, Pleistocene, and Holocene). Additional resource for the students included maps of Florida and a geologic time scale that included both the periods and epochs associated with the Cenozoic era (~23 million years – present). The students were encouraged to investigate all the materials and take advantage of the unique opportunity to physically handle authentic fossils dating from the Miocene to the late Pleistocene. Using the resources provided, students answered a series of questions building upon previous knowledge gained during lower-level questioning. Students were evaluated based on their thoughtfulness and completeness in answering questions on the *Fossil Finds* worksheet. This activity was designed to lead into the second activity: *Climate Data Interpretations*.

Although the *Fossil Finds* activity was designed for Florida high school students and based on an actual fossil excavated in northern Florida, this activity can be easily modified for many regions throughout the United States. During the early Cretaceous era (~65 - 144 million years ago) much of North America was submerged beneath an ocean. Due to this expansive oceanic environment marine fossils can be found in many regions throughout United States. Additional information regarding the North American continental sea during the Cretaceous era can be found at www.usgs.gov.

How Do Scientists Know That Climate Changes

As it is impossible to travel back in time and experience Earth's ancient environments, scientists use indicators of past environmental change. Naturally occurring indicators of environmental variability that are used to reconstruct ancient ecosystems are called proxies. Proxy data provide scientists with evidence of environmental change for periods before instrumental recordings were available. This activity exposed students to the science behind the biological concept of climate change from multiple sources. Authentic data helped students connect the inquiry processes to subsequent products of the scientific investigations, such as data interpretation, theories, and the development of models (McLaughlin, 2006). Additional information regarding paleoecological research and applications are available on the Internet sites found in Table 1.

Activity 2: Climate Data Interpretations

Objectives: The students will be able to:

- compare climate change data from a variety of sources;
- interpret data and draw conclusions about climate change.

The *Climate Data Interpretations* activity introduced students to specific marine proxies used by scientists to investigate climate change. Four different proxies were used to provide corroborating evidence for the changes in Earth's ancient climate. Multiple indicators of climate change spanning similar time scales provided students with robust evidence of climate change through time. This activity was designed to provide students with the science behind current concerns associated with climate change and the threat of global warming.

Table 1. Paleoecology research groups, resources, and websites to acquire further information

Research group	Resources available	Website
Integrated Ocean Drilling Project	Information on deep-sea drilling and opportunities for teacher to participate in paleoecology research	http://iodp.tamu.edu/
National Oceanic and Atmospheric Administration	Climate data from tree rings, charcoal, ice cores, pollen, and coral chemistry	www.ncdc.noaa.gov/paleo/paleo.html
National Science Foundation, Integrated Ocean Drilling Program	Climate change data, climate change triggers, ocean drilling research, mass extinction events data	www.nsf.gov
Neotropical Pollen Research Group	Paleoecology field work information, laboratory analysis, and applications for paleoecology research	http://research.fit.edu/paleolab/
United States Geological Survey	Climate change data, sea level, data, Earth's geological history data	www.usgs.gov

Student groups were provided one of four possible data sets from a specific paleoecological proxy used to reconstruct sea surface temperatures (available for free at www.noaa.gov) and a summary about how that specific proxy is used to derive climate information. Since more than one student group received the same data set, students were able to compare their results and interpretations with other student groups that used the same data set. The four data sets were derived from foraminifera species abundance, foraminifera Mg/Ca ratios, alkenone chemical composition, and coral bandwidth and density.

Using the information provided in both the data set and the summary, students created posters that they presented to the class. The student posters all included a title, authors, introduction, bulleted facts about the specific proxy used, a graph of the data set, and a summary that included an interpretation of the graph and how changes in sea surface temperature may influence ocean salinity, density, and species survival in marine ecosystems. Student groups presented their posters to the class and as a class we discussed the posters, climate change, additional indicators of climate change, and why climate change has become a buzzword. Student learning from this activity was assess using a simple rubric that was designed to guide students through the poster process and draw upon their knowledge of the material from this activity and the previous activity, *Fossil Finds*.

Consequences of Climate Change

Understanding Earth's climate history is essential for understanding the possible future implications of climate change (Overpeck, Cole, & Bartlein, 2003). Many studies used climate proxies, such as microfossils, to document changes in the distribution of plant and animal species. For example, Stuart et al. (2004) used radiocarbon dating of microfossils to document shifts in the distribution of wooly mammoths across Europe and Asia. This study provided evidence that this species underwent dramatic range shifts driven by climate change and subsequent vegetation changes. Paleoecologists have argued that environmental changes, such a rapid global warming, may overwhelm evolutionary processes, except, in regions that remain within species' climatic tolerance limits (Bennett, 1997). However, species that are unable to adapt or migrate quickly to keep pace with climate changes may experience higher rates of extinction. For example, many sedentary marine species may be impacted by widespread extinctions due to rapid global warming (or cooling) and associated changes the ocean environment, such as, water depth, temperature, chemistry, and available nutrients. This third activity in the paleoecology module allowed students to explore some of the potential consequences of a warming climate in a coastal ecosystem they designed.

Activity 3: Oh! It's Getting Hot In Here!

Objectives: The students will be able to:

- demonstrate the impact of sea level rise on a costal ecosystem;
- discuss the political, economic, and environmental impact of sea level rise on their model coastal habitat.

During activity three student groups designed a model of a coastal ecosystem on graph paper and then transferred their design into a model using a variety of materials (e.g., 9" x 11" pie pan, sand, sea shells, play dough, pebbles, tooth picks, pipe cleaners). This activity had few restrictions. For example, the students chose the type of coastal ecosystem they wanted to model, i.e. mangroves, estuaries, highly developed, vegetated dunes. During implementation in the first class we assigned a scale for the student to use when creating the model. However, we quickly realized that the students needed to designate their own scale for the models. Once the models were complete the student groups ran the models in one of the classroom sinks and discussed the chronology of events that occurred in their model as sea level began to rise. We also engaged the whole class a discussions about the political, economic, and environmental impact of increasing sea level in coastal communities. The benefit of students establishing their own scale was that it invoked higher-level discussions regarding the impact of sea level rise at different spatial scales during the class discussion.

The students' models were evaluated using a rubric that was handed out prior to students beginning this activity. The rubric also served as a guide to help the students develop an effective model. This activity was simple, yet effectively demonstrated potential consequences of increased sea level on coastal ecosystems. Although the activity accomplished our objectives, the addition of a summative activity write-up (5-7 sentence paragraph) would have enhanced our ability to assess the student's understanding of the possible economic, political, and environmental impacts of rising sea level on coastal ecosystems.

Conclusions

Paleoecology merged naturally into the Integrated Science curriculum following chapters that introduced students to the geology of Earth and atmosphere/hydrosphere interactions. The sequence of module activities flowed easily from one to the next, although; each activity could be used individually to address the specific concept for which it was designed. This module was successfully implemented in multiple Integrated Science III classes and subsequently modified to include the additional assessments of the students.

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