

# A Student-Centered Project for Earth System History

Rebecca Teed

Science Education Resource Center, Box 860, Carleton College, 1 N. College St.  
Northfield, MN 55057, rteed2000@yahoo.com

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## ABSTRACT

This project is intended to replace some of the lectures that would ordinarily be necessary in a survey of Earth history over geologic time. The students will be taking the lecturer's place in front of the class, presenting some of the material to their colleagues. Students will work in groups on a single era or period. Each student role-plays an expert (such as an oceanographer) and works with teammates playing other sorts of experts (a biologist, a geologist, an atmospheric scientist). Their presentation will require them to do research. They will be constructing resource lists to keep track of how they learned what they are presenting and beginning a critical analysis of resources found on the World Wide Web. They will also write brief individual summaries of the findings within their area of expertise. While the students are researching and preparing their presentations, the instructor will start giving lectures on the earliest time units, modeling the kind of presentation that the students will be doing. Eventually, students will take the stage, presenting their time units in order. Rubrics for assessing the presentation and the resource list are included.

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## INTRODUCTION

Earth history is a subject that has become overwhelmingly broad as it has expanded from paleontology into a study of the development of the entire Earth system. Nonetheless, the whole 4.6-billion-year package is often taught as a one-term survey course, often for non-majors, because it makes a fascinating story and illustrates so many important basic principles of Earth science, including plate tectonics and evolution. Upper level Earth history courses are available in many institutions.

Every week, discoveries come pouring in that add detail to every eon, era, and period, adding simultaneously to the appeal of the course and the volume of material to be covered. A combination of lectures and reading throughout the term will get the class through the material, but how much do the students actually retain after the final exam? And do they really understand evolution, plate tectonics, and biogeochemical cycling, the main subjects of Earth system history, or do they simply memorize some of the more interesting events and associated dates?

Many instructors rely on inquiry-based learning techniques that allow students to discover as much of the material as possible for themselves (e.g. Savarase, 1998). Inquiry often enables students to gain a deeper and better understanding of science than they can achieve through a simple lecture course, in both introductory survey classes (geology: McConnell et al., 2003; physics: Hake, 1998) and upper-level classes (chemistry: Paulson, 1999, Williamson and Rowe, 2002). Likewise, cooperative-learning activities that have students working together on projects show significant increase in amount and depth of learning according to a number of

studies at various institutions (Johnson et al., 1991). However, inquiry generally takes longer than does lecture, even for carefully-prepared exercises (e.g. Francis and Byrne, 1999).

The ideal teaching method for Earth history, especially if Earth system science is involved, combines the breadth of coverage of lecture with the depth of understanding of inquiry. It is perhaps more realistic to strike a balance between the two techniques. Instructors do not want to reduce course content in order to increase depth of understanding, but Earth system history is not really about facts; it is about big ideas like plate tectonics. Students need deep, long-lasting understanding of those central concepts, not about the number of mass extinctions or the number of Pleistocene glaciations (especially if research changes the numbers every few years!).

The exercise detailed below is an attempt to combine lecture and inquiry in order to enjoy the benefits of both approaches. The instructor starts by grouping students in teams and assigning each team a time-unit (usually a period, such as the Carboniferous or the Quaternary). Each student takes the role of an expert on one aspect of the Earth system (like the atmosphere or biosphere) and researches their subject of expertise within the time unit while their teammates research other aspects, so that they can work together to understand that stage of the development of the whole Earth system. The instructor will need to stress to the group that the processes that the students learn for the time-unit they specialize in operate in all intervals of Earth history, including the present! In order to continue the survey, each group works on a different time period and presents a brief summary of the development of the Earth system during their period to the other students. The instructor should present the first time-units (the Hadean and Archean at the very least), giving students a good example of how to do their own presentations.

In addition to facts, this project helps students learn skills that will help them in other classes and in their careers. College graduates often get jobs requiring them to research topics and present their findings. Likewise, teamwork, especially when it involves delegating tasks and then synthesizing results, is an important set of skills for the job world. Students also learn to structure tasks and assess their own and others' work using rubrics and can use the instructor's lectures to model their own presentations.

## ACTIVITY

This activity is set early in a course on the development of the Earth system that starts with an overview of Earth history then moves on to specific systems and mechanisms. Such a course could be taught to non-majors, majors, or graduate students (such as teachers). During this project, students will role-play subject experts on a sphere within the Earth system and work with teammates doing interdisciplinary research on one era or period in the development of the Earth System. They will keep track of useful resources as they

<p><b>Geologist:</b>  How are the continents arranged during your time unit?  What kinds of rocks and sediments are characteristic of or distinct within your time unit?  Where would one go to find modern exposures of rocks from that time unit?  Is there notable volcanic activity? Are there any impact craters from your time unit?</p>
<p><b>Oceanographer:</b>  What are the sea levels of your time unit like relative to the present? How did they change during your time unit and what caused those changes?  What kinds of conditions were there on the sea bottom? What kinds of reefs were there?  Describe the inland waters: lakes, rivers, and seas.  What types of glaciers existed? What were their temporal, latitudinal, and areal extents?</p>
<p><b>Atmospheric Scientist:</b>  What was the climate of your time unit like relative to the present?  How did climate change in this interval and what drove those changes?  What were concentrations of atmospheric oxygen and carbon dioxide like relative to the present? Did they change?</p>
<p><b>Biologist:</b>  What were the dominant kinds of animals, plants, and microbes on land and in the sea?  How did Earth's biota change during your time and what were the ramifications of those changes?  If there were extinctions, how severe were they and what caused them?</p>

**Table 1. Roles and some recommended research initiatives.**

prepare short individual papers and a group presentation, carefully examining resources found on the internet. Finally, they will present their findings to the class.

**Introducing the Activity** - At the very beginning of your course, you should inform your students that they will be presenting some of the material in upcoming classes. Assign a role to each student: oceanographer, atmospheric scientist, biologist, or geologist. Group them into four-person teams containing one "expert" of each type and assign each group an era or period. It is possible to split roles in order to create 5-person teams (i.e. the biologist could be divided into marine and terrestrial). The number of teams and the time available for the project determines the best way to choose geologic time units for each student group. You should lecture on the earlier units and assign the later units for student research. For example, in a small class of two teams, one team gets the Mesozoic and the other gets the Cenozoic. If there are six teams, assign the Carboniferous, the Permian, the Jurassic, the Cretaceous, the Tertiary, and the Quaternary. Hand each team a copy of the rubrics before they begin (Tables 1-4).

There are several reasons to lecture on earlier time units (and problematic ones like the Triassic Period). Later time units will be much easier to research and are generally simpler from an Earth systems development perspective (Cloud, 1988). The first few lectures will

allow you to model how you want the presentations done. Present the material as you would have them do it: going through developments in all four spheres, emphasizing highlights like bolide impacts and high levels of volcanism, including dates when possible and references where appropriate. Ideally, since you have explained the assignment before your first lecture, the students will watch and listen carefully while you are lecturing. Stress your sources of knowledge and summarize trends graphically whenever possible. Also point out events (noting dates) that involve several disciplines. If possible, prepare a resource and summaries (described below) for each of the time units that you lecture on for your students that are good examples of the ones that you expect from them.

**Student Research** - This research can be done outside of class, but students should plan to meet and share information during the process. If possible, arrange for each team to have their own internet bulletin board for exchange within the group. In-class meeting time also encourages students to discuss their findings and progress with their teammates. Each student will focus on his or her sphere, but should work with colleagues on interdisciplinary issues like glaciations and mass extinctions. Specific recommendations for research initiatives are included in Table 1. The students will need internet access. Check in with each group at least once to ascertain and encourage their progress, suggest good starting sources, and ask questions to lead them to interesting facts. The summaries need to be written by the individual students responsible for each subject (e.g. biosphere), but students can (and should) do the research together and draw each other's attention to material relevant to each other's summary. Encourage students to acknowledge each other's help in finding and discussing material in an acknowledgements section.

After the students have had a chance to do their research (about two weeks later), all groups should turn in their resource sheets (see rubric: Table 2), each individual should turn in their summary (rubric on Table 3), and the groups should begin work on their presentations. They should keep copies of the summaries from which to build the presentation. The instructor needs to evaluate the summaries as soon as possible because poor summaries are a warning of weak teamwork; it's time to talk to the group about cooperation. If possible, grade the resource sheet and return it to the team before the presentation so they can revise it for distribution.

**Presentation** - Once you have finished with the early units, each group should give a 20, 30, or 40 minute presentation (depending on the level of the class and the amount of time available) with 10 minutes at the end for questions on their time unit. If a group is nervous about this step, suggest that they rehearse their presentation. The instructor should provide appropriate materials for audiovisual elements: large sheets of paper and markers for posters, or a computer and projector, etc. Guertin and Nguyen (2003) suggest lending students fossils or rocks from the appropriate time unit to pass around to the audience during their presentation.

Each student should give part of the presentation. Some teams will miss items, but these oversights can be addressed in the questions after the presentation, which you can answer if they can not. In order to involve the rest of the class more, have each team rate the other

<b>Rubric Criterion: Varied Resource List</b>			
<b>4</b> At least 6 URLs, 2 articles, and 3 textbook references.	<b>3</b> At least 6 URLs, 1 article, and 3 textbook references.	<b>2</b> At least 5 URLs and 2 textbook references.	<b>1</b> At least 4 URLs and 1 textbook reference.
<b>Rubric Criterion: Critical Review of Internet Resources</b> For each online resource, please include:			
<ol style="list-style-type: none"> <li>1. A specific explanation of what it offers (i.e. a catalog of fauna, information about the origin of rock formations, links to more resources, etc.)</li> <li>2. Information about how recently it has been updated</li> <li>3. Who has produced the resource?</li> <li>4. Why was it being produced and maintained?</li> </ol> "Unknown" is a possible answer for items 2-4.			
<b>4</b> All 4 items listed above for all URLs	<b>3</b> At least 3 of the 4 items for all URLs or all 4 for most.	<b>2</b> At least 2 of the 4 items for all URLs or 3 for most.	<b>1</b> At least 1 of the 4 items for all URLs.

**Table 2. Resource sheet rubric.**

presentations using the presentation rubric (Table 4) by circling the appropriate numbers (but encourage written comments too) and turn in their to you. At the end of the presentation, the group can distribute copies of their revised resource sheet to the rest of the class.

**Debriefing** - After the class has finished presenting the Quaternary and before you finish or move to the next unit of the course, it is worth asking your students for lessons learned in their careers as Earth history experts. Discussion items could include:

- What did they think of the variety of resources available for their time-unit? Which ones were the most useful and why? What kinds of different purposes did various resources serve?
- Which spheres were easiest to research for each period? What sorts of general knowledge did the student need in order to study events affecting their sphere?
- Have each group describe a major event that occurred during their time-unit that involved more than one sphere.

**Or Segue to a New Project** - An alternative to simply debriefing the students, especially if there is plenty of class time left, is to have the students review broad trends in Earth history and the factors that drive them. Dissolve the time unit groups and form new groups based on the students' areas of expertise: one or more groups each for atmospheric science, others for oceanography, biology, and geology. For a large class, rather than have one group for each subject, break the students up further into groups of three to five and assign the groups different questions or different parts of a question.

For this project, the students can look at larger patterns across geologic time, and the evidence used to work out those patterns.

- An oceanography group could present a long-term sea-level curve, explain how it was constructed based on different kinds of evidence, and describe the forces driving those changes.
- Biologists could present mass extinctions, discuss their causes, what part extinctions play in stratigraphy, and/or whether mass extinctions occur according to a 26-million-year cycle.

- Geologists could work on orogeny and weathering patterns, such as the history of mountain chains of North America.
- Atmospheric scientists could discuss climate reconstructions of the last 100+ million years, the evidence upon which they are based, and changes in the carbon cycle

Rubrics for this project can be modified from Table 4, and related individual assignments would be useful. While students are doing research and preparing their presentations, your lectures will again model this kind of presentation. For example, you could do a biology lecture summarizing the diversification of life over geologic time, highlighting the origins of major modern taxa, and explaining

At the end of the course, after the last student presentations, you can focus on tying together different fields. For instance, you could describe theories about changes in the carbon cycle caused by increased rock weathering rates brought about by the uplift of the Tibetan plateau.

## PEDAGOGY

Lectures allow an instructor to maximize the amount of material delivered within a given time span, but this effort is poorly spent if students are not able or ready to receive the information. However, student-driven learning takes more time. Given a large volume of material to cover, if not to master, and a limited amount of time in which to do it, perhaps the ideal strategy is to combine (or at least alternate) student-driven science with lectures, especially if the combination helps the students understand and retain more of the material in the instructor's lectures. Even so, the projects above will take somewhat longer than simple lectures and are not practical for larger classes (more than thirty students).

The student project breaks the big task (for a student) of delivering a general lecture on a time-unit's worth of Earth history into smaller, more manageable tasks. Casting the students as experts, and making them researchers and lecturers will boost their self-esteem, which is helpful at the start of an intimidating class, especially for students who are non-majors. Specializing the roles (i.e. atmospheric science) will make the task of actually becoming an expert considerably easier and generate interdependence within the group. It also

<b>Rubric Criterion: Summary Content</b>			
<b>4</b> Clear, accurate description of your subject during the time unit in question, and major events occurring during the time unit with dates (even if approximate).	<b>3</b> Clear description of your subject during the time unit in question, and major events occurring during the time unit with some information about when they occurred.	<b>2</b> Summary includes information about the time unit in general and your subject in particular.	<b>1</b> Some description given.
<b>Rubric Criterion: Summary Sources</b>			
<b>4</b> All specific (not general-knowledge) information in summary cited, references on resource list or an addendum to it.	<b>3</b> Most specific (not general-knowledge) information in summary cited, references on resource list or an addendum.	<b>2</b> Some information in summary cited, references on resource list or an addendum.	<b>1</b> Information in summary came from the resource list.
<b>Rubric Criterion: Summary Form</b>			
<b>4</b> Summary is a page or less with margins at least an inch, font at least 12 pts, with correct spelling and grammar.	<b>3</b> Summary is a page or less, legible, and has good spelling and grammar.	<b>2</b> Summary is less than two pages and has good spelling and grammar.	<b>1</b> Summary is less than two pages and is legible.

**Table 3. Individual summary sheet rubric. Unlike the other two assignments, this is an individual project. Your team did some of the research, but you must each write a summary on your own. However, these summaries can become the foundation of your group presentation.**

makes the roles that the students are playing a bit more believable. Experience with library and internet research will develop skills valuable for other classes and for their future lives, such as the use of search engines, and critical examination of internet material.

The summaries provide individual accountability (Johnson et al., 1991), discouraging individuals from taking advantage of their teammates. Weak summaries will warn the instructor that particular teams and individuals are having trouble and that the instructor may need to intervene. The group resource list will promote communication among teammates during the research phase of the project. The rubrics (Tables 1-3) encourage students to assess their own and each others' work and to communicate with one another to improve their final products.

During the presentation and the preparation for it, the group provides mutual support to its members to overcome fear of public speaking. The presentation requires them to compare notes (even completely-written summaries) and to synthesize the information. To stay within the time limit and to satisfy the rubric, the students will have to organize and prioritize the information to decide which parts they want to deliver. The presentation itself will help them to develop their graphic arts and public speaking skills.

## IMPLEMENTATION

I have used a version of this activity once so far in a summer course for middle-school and high-school teachers. The rubrics provided should also work for introductory students, but should be modified for geology majors. In particular, the number and nature of sources (see Table 2) may be more demanding for geology majors. Use of primary literature rather than textbooks may be appropriate. In particular, it would be interesting to have upper-level student groups examine controversial events (such as the cause of the

Permian-Triassic extinction), and cite data that supports each side of the argument.

Research and public speaking may be challenging for introductory students. Because of the logistics of my course, library access had to be substituted with a box of textbooks and folders of photocopied articles which made research a great deal more straightforward, particularly for topics like sea level change that may be tricky for an introductory student to find easily. Likewise, an instructor can place useful starting materials on reserve in the library. An instructor can help students start finding internet resources by adding a helpful links list to the class web page. Encourage introductory students to practice their presentation together before they give it to the class.

Two-thirds of the teachers I worked with rated this exercise "absolutely useful" and one third rated it "sort of useful".

## CONCLUSION

The major goal of this project is to turn the students into minor experts on individual time-periods in Earth system history. Recurring themes can be learned in one period and applied to others: the relationship between volcanism and atmospheric carbon dioxide or between glaciation and sea level, and ideas like evolution and plate tectonics. The knowledge of novices and experts differs with respect to quality, not just quantity (National Research Council, 2000). Experts think, perceive and even learn differently. Deep knowledge of a subject helps experts to recognize patterns within facts and to prioritize relevant facts over irrelevant ones. The paradigm designed to make novices into experts is apprenticeship (Farnham-Diggory, 1994). For the project above, apprenticeship involves a combination of observational and experiential learning. During the first few lectures, the professor demonstrates, and the students watch and learn, not just the material but how to communicate it. As they research, students are

<b>Rubric Criterion: Presentation Content</b>			
<b>4</b> Detailed, accurate description summarizes the distinctive features and events and the development of all four major spheres throughout the time unit by period. Includes dates!	<b>3</b> Description includes information about the development of all four major spheres throughout the time unit and summarizes its distinctive features and events. Few if any errors.	<b>2</b> Description includes information about global changes occurring during the time unit and includes some distinctive features and events of the era.	<b>1</b> Some description given.
<b>Rubric Criterion: Presentation Form</b>			
<b>4</b> Clear presentation employing helpful audiovisual support with a world map, does not exceed time limit, presenters can answer all questions.	<b>3</b> Clear presentation, employing helpful audiovisual support, includes a world map. Presenters can answer most questions.	<b>2</b> Understandable presentation, includes audiovisual support.	<b>1</b> Material presented to class.
<b>Rubric Criterion: Presentation Participation</b>			
<b>4</b> All team members contribute equally.	<b>3</b> Team members vary slightly in quantity or quality of material presented.	<b>2</b> Team members contribute unequally to presentation.	<b>1</b> Not all team members present material.

**Table 4: Presentation rubric.**

practicing scholarship, with some help from the instructor, both in the form of informal leads and questions and as formal feedback on their resource list and summaries. Finally, the professor disengages and allows the students give their lecture, providing a little support, if needed, in the question section.

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