

A Multi-Disciplinary Earth Systems Course Designed for Pre-Service Middle School Teachers

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ABSTRACT

Earth Systems, a new course developed expressly for pre-service middle school teachers, was developed in response to new Ohio Academic Content Standards in Science and the rigorous Ohio Graduation Test. The course is designed to increase students' content knowledge, research skills and confidence in teaching Earth systems science. It is broken into three modules in which students examine volcanic eruptions, global warming, and the latest ice age. Working in teams, the students determine how each of the above phenomena affects and is affected by Earth's systems. The students then jigsaw into new teams to work out how the various effects in the system create positive and negative feedbacks that determine the ultimate impact of the event (eruption, etc.) on the Earth system. Each group produces a report that is assessed using a rubric. Students are individually assessed through lesson plans and journals.

INTRODUCTION

Starting in 2007, all students in Ohio will be required to pass a high-stakes statewide Ohio Graduation Test as a requirement for their high school diploma. Earth systems are an organizing theme woven through the benchmarks that will be tested. In 2002, the Ohio State Board of Education adopted Academic Content Standards for K-12 science. The overview in this document states that K-12 students studying Earth and space science will:

demonstrate an understanding of how the Earth systems and processes interact...how the concepts and principles of energy, matter, motion and forces explain Earth systems...and grasp an understanding of historical approaches and scientific approaches. (Ohio Department of Education, 2003)

In order to help prepare K-12 students for success in the Ohio Graduation Test pre-service teachers need a high level of content knowledge and a deep understanding of the complex interactions that characterize the natural world and human society. Although the Ohio Graduation Test is administered in March of a student's sophomore year, the Ohio legislature has mandated that the ninth and tenth grades of high school science be focused on physical science and life science respectively. Because of these course

restrictions many school districts either choose to integrate the Earth and Space science benchmarks into the ninth and tenth grade physical and life science courses or to teach the ninth and tenth grade Earth science benchmarks in the eighth grade. School districts that choose to teach Earth and space science during the eighth grade need to be sure that the middle school science teachers they hire are themselves academically prepared to teach high school science benchmarks.

To prepare our middle school pre-service teacher candidates to better serve their future students, the Department of Geological Sciences at Wright State University developed an inquiry-based course titled "Earth Systems".

THE EARTH SYSTEMS COURSE

The Earth Systems course integrates content and pedagogy. Class size is limited to approximately 24 students. The course uses an integrated lecture/lab learning environment (Slattery, 1996) designed to build their science content knowledge and to provide models for their future classrooms. It meets for six hours per week during the ten-week quarter and carries 4.5 quarter hours (3 semester hours) of credit. Course content is aligned with state and national 9-10 Earth/space science standards (Ohio Department of Education, 2003, National Academy of Sciences, 1995) because, as stated above, in many Ohio school districts, middle school teachers play a key role in delivering the content necessary for the Ohio Graduation Test. The Earth systems course is built around three learning modules, each of three weeks duration. Each of the modules is designed to develop interdisciplinary science content within the context of past, present and future Earth systems science.

Module One - Volcanoes and the Modern Earth System - The Ohio Graduation Test requires K-12 students to answer short- and extended- response questions, not just multiple-choice questions. K-12 students must understand the science content and be able to fully explain their understandings to be successful on this high-stakes test. Therefore, assessment in our course is based mostly on student writing.

Each student begins the unit by writing a journal entry summarizing his or her initial knowledge of the topic and where they learned that information. Most of the research and content learning for each module is done by students working in teams assessed using an instructional rubric for course writing assignments that asks students to write content explanations stating

Grading Criterion	4	3	2	1
Accuracy	Presents precise and meticulous scientific understanding.	Conforms nearly exactly to accepted scientific understanding.	Deviates only slightly from accepted scientific understanding.	Strays from accepted scientific understanding.
Depth of Reasoning	Reasoning completely supports the hypothesized effect or interaction.	Uses scientific reasoning, concepts and processes to explain the interaction.	Includes science concepts and processes in the reasons for the effect and the interaction.	Explains at least two reasons for the effect or interaction.
Quality of Support	Compelling use of existing research and knowledge.	Uses logical support that is convincing using data and authority.	Uses reliable data from multiple sources.	Uses relevant and respected authorities.

Table 1. Rubric used to guide the development and grading of the Sphere Group and Event Team reports (ESSC, 2001)

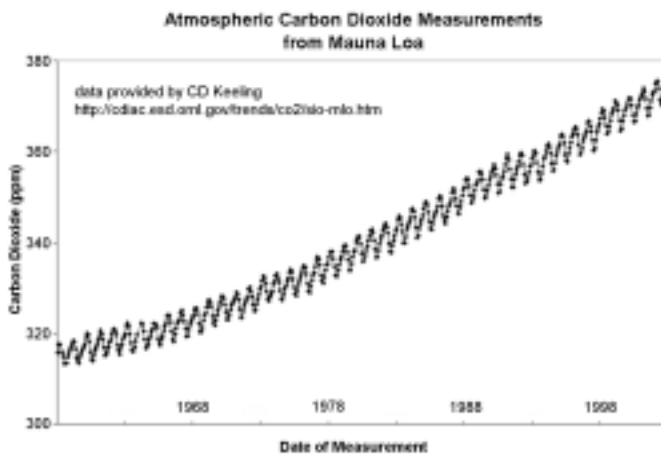


Figure 1. Atmospheric Carbon Dioxide Measurements from Mauna Loa (Keeling, 2002)

correct facts and assertions, describing and explaining fully those facts, and citing sources (Table 1). The same rubric students use to guide their report writing is the same rubric that is used to grade their efforts.

An excellent resource for developing the research skills and Earth systems understandings already existed as a part of an on-line Earth System science course for in-service teachers. This on-line course was developed by NASA and The Center for Educational Technologies and has been taught by a consortium of universities and regional educational service centers, including Wright State University, for several years (Schwerin et. al. 2006). The Middle School on-line course can be accessed through the Center for Educational Technologies website at <http://www2.cet.edu/ete/5-8/main.html>. We adapted some of the learning activities for use in the new Earth Systems course.

During the first week of the module students work together in "Sphere Teams" to study the impact of the volcanic eruption of Mount Pinatubo. Each team is assigned an Earth sphere (atmosphere, biosphere, hydrosphere, and lithosphere). The objective of the each group's discussion is for each team member to become as knowledgeable as possible about the impact the eruption of Mt. Pinatubo had on their group's sphere. At the end of the module's first week, participants have collected

and discussed information concerning their sphere and write a group report based on the rubric in Table 1.

In the second week, new teams are formed to develop interactions between the different Earth system spheres. Each "Event Team" is composed of at least four students, one (or more) from each of the different sphere teams from the previous week, using a classic jigsaw technique (Aronson, 2006). Each member is counted on for knowledge developed during the previous week's sphere group discussions. Each group develops a written study of the feedback loops of connections between the spheres and the event. If all members of the group do not contribute roughly equally to the project, the instructor intervenes and assesses individual contributions separately. Since much of the group work is done in class, the instructor can evaluate participation directly, and we have used peer review on a few occasions to identify groups that were having difficulties.

During week three, students work in groups to connect the content understandings they have developed in Module One with the Ohio Academic Content Standards and work to decide how they would deliver standards-based content in a middle school classroom. Each student writes an individual lesson plan on each topic, incorporating both the student's enhanced content knowledge and pedagogic experience. The lesson plans (graded using another rubric) must be interdisciplinary, use jigsawing, include a "hook" to engage the students, and assess learning throughout the lesson using rubrics. At the end of each unit, each student writes another journal entry explaining how and why their understanding of the topic has changed.

Module Two - Global Climate Change and the Future Earth System - This module's focus is on understanding rates of change and the interpretation of graphs. Students usually don't give much thought to the different timescales of Earth system processes. To study global warming and climate change in general from an Earth systems perspective, students need to understand the carbon cycle. During week one, teams of students investigate the biological and geological carbon cycles. Changes in the biosphere, such as spring leaf-out in the northern hemisphere have visible effects on carbon dioxide concentrations in the atmosphere within a year (see Figure 1). Rock weathering and tectonic plate motion rates do not change that quickly; but over the last ten million years, the increased weathering of the Tibetan plateau and the Himalayas have caused a marked

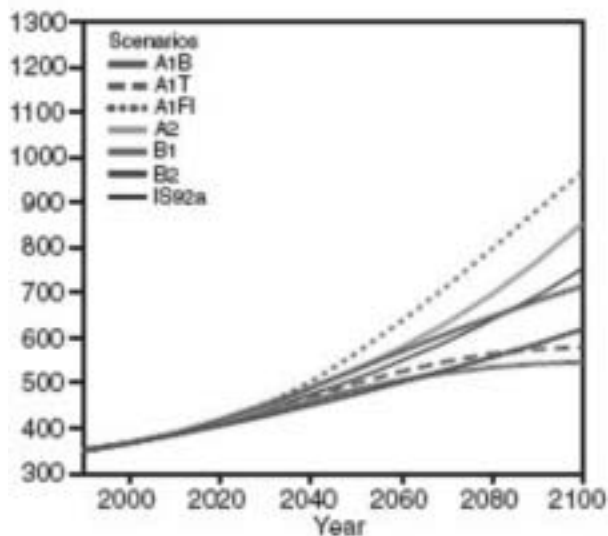


Figure 2. IPCC summary of projected carbon dioxide emissions for the 21st century (IPCC, 2001)

cooling in global climate, making recurring ice ages possible (Ruddiman, 2001).

During week two, students compare the rates of plate-tectonically-controlled cooling with the rate of anthropogenic induced global warming. They see that over the next fifty years, a time-scale of personal significance to the students, there will likely be a considerable net increase of carbon dioxide in the atmosphere (Figure 2).

During week two students also investigated human activity that may enhance the amount of carbon dioxide in the atmosphere. The class chose to examine global deforestation rates and realized that not only are humans adding carbon dioxide to the atmosphere, they are reducing the ability of the biosphere to take it back up. Week three engages students in the writing of Earth system science reports using the same rubric as they used in the first module (Table 1) and presenting their results to their peers.

Module Three - The Pleistocene Ice Age(s) - In their research for the previous module, a number of students discovered that there has been extensive climate change in the past. Some will have learned during their research in the second module that there have been multiple ice ages in Earth's past, varying in intensity and duration. We find that an interesting way to begin is to ask students to define an "ice age." Most say it is a period of time in which permanent ice sheets are present. However, according to this definition, we have been in an ice age for the last 14 million years, and the previous ice age was almost 250 million years ago. It's a nice, consistent definition, but one that causes them to rethink their prior conceptions.

However, many students believe that the latest ice age ended 10,000 years ago. To explain away this conundrum students backpedal and redefine an Ice Age as requiring an ice sheet over Canada and Scandinavia. This more complex definition must involve a careful consideration of timescales because there have been 17-36 such ice ages in the last 2 million years (N. Shackleton, personal communication).

During week one, teams investigate rates of change in past climates. For instance, during the last 800,000

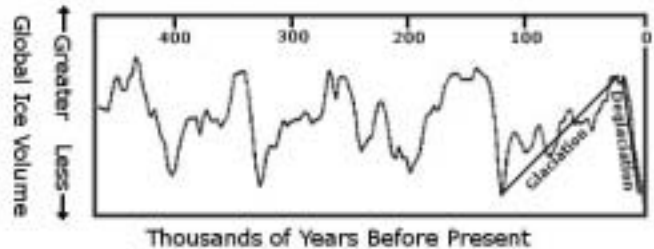


Figure 3. Ice volume changes over the last 450,000 years (modified from Imbrie and Imbrie, 1979, based on data from Hays et al. 1976)

years, ice ages last on average about 100,000 years each and the warm periods between them (like the present) are about 10,000 years long (Hays et al., 1976). The students also examine the "saw-toothed" shape of the global ice volume curve. The ice sheets increase in volume gradually over tens of thousands of years, but melt unevenly over centuries to tens of thousands of years (Figure 3; Imbrie and Imbrie., 1979 and Hays et al., 1976). During week one, the students also focused on positive and negative feedbacks and how these affect the rate of ice volume change and sea-level rise and fall through time.

During week two, students work in groups to explore the matrix surrounding the skeleton of a mastodon that was found a few years ago in up-state New York. Researchers at Cornell University developed a program that engaged K-12 classroom teachers in gathering and reporting data back to researchers (Ross et al., 2003). Our pre-service teachers picked through the matrix and found a substantial number of twigs and other plant material. They were able to identify some of the material as spruce and pine twigs. The teams decided that perhaps the trees were now living north of where the mastodon was found and that perhaps the twigs could be a clue to how the climate had changed over time. Although the results were inconclusive, they gained valuable knowledge and research skills along the way. Week three engaged students in the writing of Earth system science reports using the same rubric as they used in the first module (Table 1) and presenting their results to their peers.

CONCLUSION

The Earth system science class is itself part of a system. The curriculum of prior courses, faculty/student interactions in previous science courses, and the conceptual knowledge and attitudes that students bring into the class interact in a complex way for every individual student. During the first class meeting, students were asked the science content area in which they felt they had the most content knowledge. Seventy percent of students responded that they felt they knew the most content in the physical sciences. Twenty percent felt their content strength was in the life sciences and ten percent of the students believed that Earth and space science was their strongest content area. The Earth system science course was usually one of the last courses taken by students completing a Middle Childhood science concentration, so one of the assessment goals of

the course was to determine if students have the science content knowledge they need and the skills and attitudes necessary to lead their students to success on the Ohio Graduation Test. This was not surprising, as the transcripts of the students showed that the Earth systems science class was the last content course for over sixty percent of the students.

To determine if students had acquired the necessary content knowledge, students were administered the Twelfth Grade Ohio Proficiency Test in science. This test is aligned with the most rigorous high school standards, benchmarks, and specific grade level indicators. Although the pre-service Middle Childhood Licensure students might be asked to teach only up to the tenth grade science benchmarks, knowing as much science content as high school teachers need to teach is considered a strong positive achievement and provides them with added confidence. At the start and the end of the first section of the course taught, students were given the Twelfth Grade Ohio Proficiency Test in science as a pre-post measure of their change in Earth science content knowledge, and their scores increased an average of 39% (+/- 13%).

Our future generation of citizens will probably be asked to make hard choices dealing with non-renewable and renewable energy resources, global warming, and environmental pollution. Will they be swayed by persuasive, misleading rhetoric, or will our next generation of citizens have the science literacy skills to make wise choices? Building pre-service teachers' ability and confidence to build their own science content knowledge makes it more likely that the rising generation of K-12 students will have the skills necessary to make the hard choices they will face.

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