PROJECT REPORT

Teaching Through Human-Driven Extinctions and Climate Change:
Adding Civic Engagement to an Introductory Geology Course for Non-Majors

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Abstract
Two of the greatest challenges facing humanity—climate change and the dramatic loss of biodiversity—are best understood through the lens of deep time. We applied SENCER principles to redevelop an introductory paleontology course at the University of Kansas (Geology 121, "Life through Time: DNA to Dinosaurs") to help general education students understand the value of our discipline in the modern world. Our process included reducing content coverage and connecting geologic concepts to modern challenges, placing students in teams and implementing active learning in every class, and including a final research project that challenged students to mitigate the current mass extinction event. While students were initially uncertain about the new course since it would require more work on their part, final student comments on the class were overwhelmingly positive, and final grades improved dramatically over past semesters, despite a significant increase in the rigor of the course overall.

Introduction
Many students enroll in introductory geology classes merely to fulfill a distribution requirement (Gilbert et al. 2012). At the University of Kansas, all undergraduate students are required to take a natural science course regardless of their major, and this class is often their only college-level science class and the last science class they will ever take. Given that two of the most pressing issues facing humanity right now—climate change and the prospect of human-caused mass extinctions—can best be understood through a geological lens, we decided to redevelop Geol 121, "Prehistoric Life from DNA to Dinosaurs," an introductory paleontology class for non-majors, according to the SENCER model. Although geology majors can take this class to supplement the required introductory geology course, the majority of the students are not majoring in a STEM field.

Traditionally, this course has been lecture-based, and student learning was gauged by measuring the student's ability to memorize details about when various animals originated and went extinct through geological time. During the redesign process, we established two primary goals to guide our efforts: (1) geological and paleontological information would be interwoven with the interconnected civic issues of human-driven extinctions and climate change, and (2) students would actively explore and discover knowledge themselves, rather than passively receiving it. By teaching through these complex, controversial, and current issues, and by challenging students to directly engage with the science, we sought to increase student understanding of the scientific method and its impact on their everyday lives. This paper describes the redesign process and preliminary outcomes.

Methods

The redesigned class was offered in Fall 2014 to 60 students. This was the fifth time Olcott Marshall had offered this class, having taught the old version four times between Spring 2009and Spring 2013, to a total of 452 students. Olcott Marshall began the redesign process in March of 2014, and was guided and assisted from that time until the end of the semester by Bitting, whose role in the department was as a teaching specialist. To transform the class, three steps were necessary: (1) streamlining the material, (2) creating opportunities for active engagement, and (3) implementing a final project that allowed students not only to synthesize and evaluate all of the information they had explored during the semester, but to apply that information to matters of immediate societal importance.

Streamlining Material

The first modification was decreasing the amount of material the course would cover. The original version of the class covered 3.5 billion years of Earth history, with each day of the class dedicated to lecturing about a different period of geological time. This much material was overwhelming to the students and did not allow more than a superficial introduction. For the new course, we implemented a backwards design approach (Wiggins and McTighe 1998): First, we established two specific student learning outcomes related to human-driven extinctions and climate change: "Students will be able to

- analyze the extinction pressures acting on modern organisms in the context of those organisms' geologic, evolutionary, and climatic history.
- construct an action plan for mitigating the current mass extinction event that is informed by their understanding of organisms' roles in and relationships with the Earth system."

Based on these intended outcomes, we determined what content material to cover in class and shifted the emphasis of the course from declarative to procedural knowledge to allow students to practice skills that would allow them to succeed in the complex tasks leading to the outcomes above. The material we identified for the redesigned course had previously been covered in only eight lectures, but now the students would explore the material in-depth over the course of 30 class meetings.

Active Engagement

In previous years, students were mostly passive recipients of knowledge in the class and were expected to study facts, dates, and terms on their own to prepare for exams. In 2009, 2011, and 2012, student grades were determined solely by four exams. In 2013, students did a short five- to ten-minute activity at the end of each lecture, but these were done individually, and since the students left when they were finished, there were few opportunities for the class to summarize, debrief, or reflect on what they were doing or why.

For the redesigned class, we wanted students to engage with the material from the very beginning, to recognize that their learning occurred through actively exploring the information, and to apply, analyze, and evaluate their newfound scientific knowledge continuously. Every class period, the students worked through a series of two or three related activities designed to scaffold them through the process of activating and building upon prior knowledge (Linn 1995; Vygotsky 1980). Some activities required students to summarize and explain the conclusions of figures from published paleontological studies, while at other times the students worked with raw data they downloaded from the Paleobiology Database (http://paleodb.org) to interpret, examine, and craft hypotheses. To leverage students' social goals (Ford 1992), and to harness the power of peer instruction (Johnson et al. 1991), some of the activities were done in groups of three or four, and others required the students to work individually before consulting with their groups (think-pair-share) (Table 1). By including a wide range of types of activities, we were able to provide instructional conditions that appealed to extroverted learners, such as

TABLE 1. Types of Activities Introduced in Transformed Class

IN-CLASS ACTIVITY TYPE		ADDITIONAL INFORMATION
Think-Pair-Share	14	Often used to activate prior knowledge or reflect on the meaning and value of content.
Team	19	Often asked students to apply, analyze, and synthesize information, including interpreting or creating graphs and crafting hypotheses to explain data. Total number includes three activities designed specifically to scaffold students through the research project.
TAKE-HOME ESSAY TYPE		
Individual	2	
Team	3	All designed to scaffold students through the research project.

interactive collaborative activities, and ones that appealed to introverted learners, such as solitary deductive sequences (Jonassen and Grabowski 2012). Additionally, in order to help students integrate their knowledge into a more coherent framework, each class period included time for them to reflect individually, in groups, and as a class on what they were learning and why (Davis and Linn 2000).

Final Project

Although the activities provided the students opportunities to appraise and synthesize information, our ultimate goal for the course was for the students to generate and defend their own research into the twin civic issues underlying the course. To accomplish this, during the last third of the semester we implemented a series of assignments to scaffold students through their collaborative final class project, which culminated in an authentic public event dubbed "Paleocon." This project required teams of students to choose a threatened modern animal and an extinct counterpart and research their habitats, ecosystems, and lifestyles. They evaluated and described how the ancient organism became extinct and extrapolated lessons learned from that extinction event to help the modern organism survive the twin specters of human-caused extinction pressure and climate change. In lieu of a final examination, the teams presented their findings to their classmates, the university, and the general public in a creative science-fair-style presentation.

Outcomes

Throughout the redesign process, we shifted the emphasis of the activities, assignments, and assessments away from simple memorization and understanding to build in more analysis, synthesis, and evaluation of ideas and information. This shift is well illustrated by a general analysis of exam questions by level on Bloom's Taxonomy (Bloom et al. 1956) in the Spring 2012 (traditional) and Fall 2014 (redesigned) semesters, shown in Figure 1. We acknowledge that grades are not a proxy for learning and

Figure 1: Distribution of exam question Bloom's level from Spring 2012 (traditional) and Fall 2014 (redesign). Prior to the redesign, all exam questions were related to the three lowest levels of Bloom's taxonomy (remember, understand, apply), with the majority of questions asking students only to remember content. During the redesign, upper levels of Bloom's taxonomy were incorporated (analyze, synthesize, evaluate) and questions were much more broadly distributed. (Total for 2014 not equal to 100 due to rounding.)

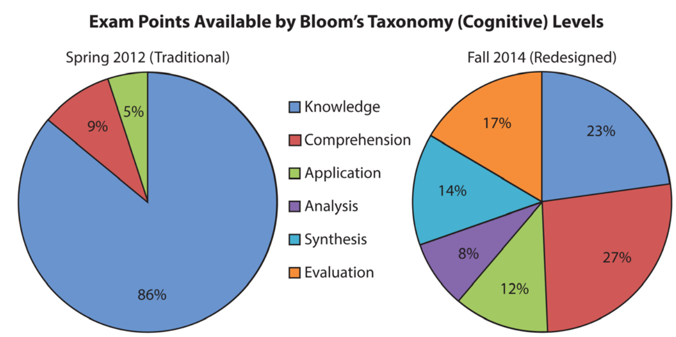


Figure 2: Grade distribution through the years that Geology 121 has been taught by Dr. Olcott Marshall; 2014 is the year the course was transformed. Final letter grades were determined by calculating the percentage of available points earned by each student then converting that percentage to a letter grade with a traditional 10-point scale. The redesigned course resulted in a much greater number of A's and B's and a significantly reduced number of C's, D's and F's.

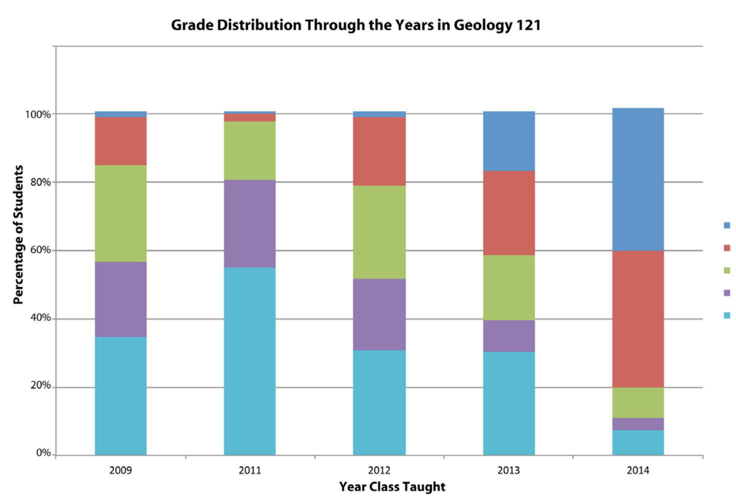


TABLE 2. Types of Activities Introduced in Transformed Class

OLD CLASS QUESTION:	NEW CLASS QUESTION:
The radioactive isotope ^{40}K decays to its daughter atom ^{40}A with a half-life of 1300 million years. If a crystal is found that is 1/16 ^{40}K and 15/16 ^{40}A, was this crystal formed on the Earth? How can you tell?	How old is the Earth? By what methodology might scientists know this age, and why?
Yes, the crystal must have been formed on the earth because it is a radioactive isotope which is often associated with volcanic activity. Therefore the crystal must have been formed on the Earth and was formed by some type of volcanic activity.	Over the years, scientists have come to somewhat of a consensus on how old the Earth really is. After extensive development of ideas, thousands of hours of research, and much speculation, the consensus on the Earth's age is settled on a ballpark figure of about four and one-half billion years. An exact age has not been able to be determined because plate tectonics have destroyed most, if not all, of the Earth's oldest rocks, which were our best means of getting to the root age of our planet (material cited: "Geologic" 2007). Scientists decided that the best way to figure out the Earth's age was by measuring the age of ancient sedimentary rocks and the decay of radioactive isotopes of elements found inside them. The half-lives of these radioactive isotopes are determined by radioactive dating (material cited: "Geologic" 2007). Once we know the actual age of the rock units, scientists are then able to place them along a timeline of Earth's history, known as the geological time scale, and then use the oldest recorded one to also represent the age of the Earth.
No. Because in this problem, you would multiply 1300 million years by 4 (because 1/16 indicates four half-lives) = 5200 million years ago. We have learned that the earth is approximately ~4500 million years old so we know the crystal was not formed on earth	No. Because in this problem, you would multiply 1300 million years by 4 (because 1/16 indicates four half-lives) = 5200 million years ago. We have learned that the earth is approximately ~4500 million years old so we know the crystal was not formed on earth The current best estimate for the age of the Earth is 4.54 billion years. Scientists have used radiometric dating on a variety of radioactive compounds contained in old, undisturbed rocks and iron meteorites all around the globe; as well as on the moon, where ancient rocks are much more plentiful due to a lack of plate tectonic movement that would destroy and remake rock formations (material cited: Watson). Using the known half-lives of these radioactive substances, and collecting samples from the rocks to find how much of the substance has already decayed, scientists can determine an approximate range of the sample rock. This would mean, of course, that the Earth is at least as old as the rock in question (the same logic applies to samples from the moon: the Earth must be at least as old as the oldest rocks found on the moon). Also, other clues from around the solar system, such as calculating the age of the Sun, have helped in reaching the 4.54 billion estimate, since the ages of all heavenly bodies in the solar system are understood to be roughly similar (material cited: Watson).

but it is striking that, although the redesign required the students to do more work and to understand the material on a deeper level than in previous years, student performance (as measured by grades) increased as well, eighty percent of the class earning an A or a B (Figure 2).

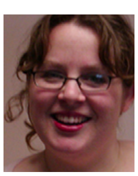
Qualitatively comparing student written work from previous years with that produced by students in the new course demonstrates increases in student engagement and ability to synthesize material on their own (Table 2).

Although the two questions asked are slightly different each year, to answer either question, a student would need to know the age of the Earth and understand the principles of radioactive age dating. In the transformed class, student work reveals a deeper understanding of the material and increased ability to synthesize different types of information than in years past.

Student success, as well as the success of the redesign, are also reflected in the students' attitudes towards the class and the material. Students were initially leery of the changes in the class, as they correctly surmised that they would be doing more work than a traditional lecture-based course would require. They also were, as one student put it, "shocked that they had to be in a group and do so much group work." However, they quickly became much more engaged with the material than in previous years; one student commented that the class "motivates us to want to learn the information and apply it to things that interest us as opposed to just being in the library and studying and then going and taking a test." Or, in the words of another student at the end of the semester: "I expected this class to be somewhat boring and easy but it was anything but that. It provides you with a lot of insight that you can carry on to a lot of career fields. It's a strong base to the information that you will gain in the rest of your collegiate experience."

About the Authors

Kelsey Bitting is a Visiting Assistant Professor and Postdoctoral Teaching Fellow for Course Redesign at the University of Kansas. She is a trained geomorphologist and sedimentary geologist, but her current research interests center on geoscience learning and the implementation of active learning in introductory courses.



Alison Olcott Marshall is a paleobiogeochemist at the University of Kansas. Her research involves using chemistry to quest for and understand fossils, and she has recently become interested in transforming her classes with the hope that students will be excited and involved in their own learning.

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