Using National Parks to Transform Physical Geology into an Inquiry Experience

Phyllis Leary Newbill[1]

ABSTRACT

For an inquiry-based alternative to lectures and recall tests, I encouraged learners to become "geotourists"; that is, learners researched and developed a geologic guidebook to a United States National Park of their choice. Over the course of a semester, students wrote chapters on plate tectonics, the rock cycle, geologic history, groundwater and hydrology, geomorphology, and topographic maps. By applying the physical geology concepts to a particular location, learners found the material to be relevant and engaging. Keys to success included developing detailed rubrics, reading multiple drafts, and using appropriate instructional technologies. Students who participated in the class reported that the project involved considerable work, but was more interesting and relevant than lecture exams.

INTRODUCTION

To address the weaknesses of the lecture-and-exam model science teaching, scholars have called for the development of inquiry and problem-based learning to enhance the effectiveness of science education (i.e., Bransford et al., 2000; Herbert, 2006). Many scholars suggest using environmental problems to make the science relevant. However, individual professors are occasionally charged with teaching Physical Geology in a course that is distinct from Environmental Geology. How can geoscience educators make a course on earth materials and processes relevant to the non-science major?

I was inspired after attending a talk by a veteran geologist who essentially presented the story of his summer vacation. He told his story enthusiastically and in the context of the local geology. He had done his homework before he went. His real world application of the concepts of physical geology inspired a new focus for the physical geology course. Like many geologists (i.e., Kieffer, 2006), his understanding of deep time, plate tectonics, and earth systems allowed him to experience the beauty of the natural world with deeper appreciation. I hoped to give my students a taste of that deeper understanding by developing a physical geology course that would teach students the process for understanding the geology of a place. In short, students could be trained as geotourists.

The National Park system includes many beautiful, geologically interesting places. National parks have been extensively studied, and there are ample web and print resources available to help citizens understand their geology.

[1]Department of Geology, Radford University, Box 6939, Radford, VA 24142 ; pnewbill@radford.edu

Excellent professional examples demonstrate how the physical geology curriculum can be used to explain places of interest. Harris, Tuttle, and Tuttle's "Geology of National Parks" (2004) and "Lillie's Parks and Plates" (2005) are two of the best print resources available. Many other publications are for specific parks. For example, Art Palmer's "A Geological Guide to Mammoth Cave National Park" (1981) served as a model for the semester-long project that is described here.

THE GUIDEBOOK PROJECT

To address the problems with traditional teaching methods, the author created an inquiry-based project in which students created geologic guidebooks to United States National Parks of their choice.

The complete guidebook consisted of seven chapters. Each chapter included some general information that was similar in all the projects and some specific information that applied the concept to each park. An outline of the guidebook is shown below:

1. Introduction
2. The theory of plate tectonics
    a. Overview of plate tectonics
    b. Description of earth's interior
    c. Present-day tectonic environment of the park
3. The rock cycle
    a. Original diagram of the rock cycle
    b. Description of the rock cycle
    c. Description of igneous rocks
    d. Description of sedimentary rocks
    e. Description of metamorphic rocks
    f. Rocks, minerals, and processes found in the park

4. Geologic and tectonic history
   a. Overview of geologic time
   b. Tectonic history of the park
5. Topographic map
   a. Topographic map
   b. Description of topographic and water features on the map
   c. Worksheet with topographic profile and calculations
6. Drainage and groundwater
   a. Hydrologic cycle
   b. Water in the park
   c. Visitors and water
7. Geomorphology
   a. Geomorphology
   b. Forces
   c. Explanation of surface features

In addition to receiving grades for each of the chapters, students were graded on the process. They were graded on participating in class, meeting deadlines, "publishing" their work, presenting their work orally, and writing a reflection on the whole process. The publishing requirement had the students create a hardcopy of their paper and bind it in a permanent or semi-permanent manner with a title page and table of contents. The students were encouraged to keep their documents to refer to whenever they might visit the park they chose.

The course was most recently taught to a group of fourteen students, but the project has been used with as many as 22. In the most recent iteration, eleven students were new freshmen, one was a sophomore, one was a junior, and one was a senior. None of them were geology majors or even science majors at the beginning of the semester. (At least one changed to a geology major following the class.) There were nine women and five men. Twelve students were Caucasian, and two were African-American. The class was taught in a traditional face-to-face classroom with twice-weekly meetings plus a weekly lab time.

BASIS AND MECHANICS

Learning theories can explain the problems with the lecture-and-test format, and they can offer insight in teaching methods that solve those problems. The problems can be understood in the context of Bloom's taxonomy, conceptual change theory, and motivation theory.

Bloom et al. (1956) outlined the hallmark taxonomy of instructional objectives that is relevant. The taxonomy includes six levels of competence: knowledge, comprehension, application, analysis, synthesis, and evaluation. Instructional objectives and test questions can be classified in these levels. For example, knowledge includes objectives that start with words like "list", "describe", "define", and "identify". Comprehension, a step higher, includes objectives that start with words like "interpret", "contrast", "predict", and "summarize". When learners get to the application level, they complete tasks where they apply, demonstrate, calculate, and discover. At the analysis level, students classify, explain, compare, and divide. At the synthesis level, learners do things like plan, create, design, invent, and compose. Finally, at the evaluation level, learners evaluate, judge, rank, and measure.

Traditional lecture-and-test based instruction, especially in the sciences at introductory levels, is typically limited to the knowledge and comprehension levels of the taxonomy. There are many reasons for this. Professors can lecture on material and reasonably expect students to get to the knowledge and comprehension levels. Tests of this level of skill are easy to construct and grade. However, analysis, synthesis, and evaluation are important to real learning. Assessing these levels requires more creativity, but is entirely possible (Doran, Chan, & Tamir, 1998).

The nature of the National Park guidebook project forced students to do more with the class information than simply memorize it. The writing portion of the project helped students rise above the knowledge and comprehension levels of learning. In most chapters, students were given a list of terms to include in their discussion and specific requirements about what information to find and include about their park. Students had to make semantic connections among vocabulary words and concepts. As they researched and wrote, they spent their time applying knowledge to their parks and analyzing information they found in their research. For example, in the Topographic Maps chapter, students had typical learning objectives, such as constructing a topographic profile, but met those objectives using maps from their individual parks. In creating the finished document with its introduction and other organizing components (table of contents, transitions), the project included synthesis-level objectives. In all these ways, the Guidebook Project encouraged students to think beyond simple knowledge and comprehension.

Misconceptions are another common problem in introductory science classes. Conceptual change theory addresses the problem of persistent misconceptions, by forcing learners to "re-conceptualize deeply rooted misconceptions" (Bransford, et al., 2000, p. 179). The process of teaching for conceptual change involves two basic steps: eliciting learners' views and helping the learners understand the competing conceptions in their own minds (Hewson, 1996). The purpose in eliciting different views is to encourage the learners to compare their personal views to other possibilities, including the accepted or preferred view. This is similar to the challenge phase described by Cosgrove and Osborne (1985) in which teachers are encouraged to compare the class's conceptions to scientists' understanding of the concept at hand.

Once teachers and instructional designers know what misconceptions the learners have, they must help the learners to understand the problems with their misconceptions and to understand the new alternative. The objective is to help the student understand why the misconception is incorrect and how the scientific theory is the correct one. Conceptual change occurs when the learner chooses a new model or understanding.

In the National Park guidebook project, misconceptions were immediately and painfully obvious. Simply assigning a project like this was not sufficient. The project was too massive and complicated to assign as a single project turned in for a final grade. To spread out the workload, students completed a new chapter or section each week. Then, I compared the student work to the requirements for the assignment using detailed rubrics. Students had two opportunities to improve their grades with additional drafts and feedback. Each chapter had a final deadline, after which scores could not be improved.

Multiple drafts were essential to fixing misconceptions. As expected, students' first drafts often revealed substantial misconceptions. In some cases, a particular misconception was ubiquitous, and I discovered that either I had confused my students or some popular web source had given them a misunderstanding. When this happened, it was worth using class time to correct the misconception. Other times, the misconceptions were isolated and individual. In those cases, I wrote an explanation, referred the student to a particular textbook page, or asked that the student stop by during office hours. The two conversations included below show how misconceptions and ill-formed conceptions were corrected using the draft method.

Example 1

Student's first draft: "Assateague Island's rock cycle material is quartz sand which is a sediment. Once the quartz sand goes through lithification, it will become sandstone. If the sandstone undergoes heat and pressure, it will become the metamorphic rock granite."

Professor's response: "Granite isn't metamorphic. Granite weathers to form quartz sand. Metamorphosed sandstone is called quartzite."

Student's final draft: "Assateague Island's rock cycle material is quartz sand which is a sediment. Granite weathers to form quartz sand and once the quartz sand goes through lithification, it will become sandstone. If the sandstone undergoes heat and pressure, it will become quartzite."

Example 2

Student's first draft: "Cape Cod Park is a shoreline. The physical features of the park are the same as a beach."

Professor's response: "What are those features?"

Student's next draft: "Cape Cod Park is a shoreline. The physical features of the park are the same as a beach. The park has water and sand in it."

Professor's response: "What are those features? What does it look like?"

Student's next draft: "…Also Cape Cod has Dunes and tidal flats in it. They are created with sand, wind and water."

Professor's response: "How are they created? Mixed together?"

Student's next draft: "…Also Cape Cod has dunes and tidal flats in it... They are created with sand and wind. The wind blows over the land and encounters vegetation or a rock the wind goes around the object leaving a shadow."

DISCUSSION

Students were not required to submit more than one draft. They were welcome to stop whenever they were satisfied with their grades. The use of multiple drafts was especially important for helping students correct their misconceptions and develop their communication of important concepts.

Meaningful products are helpful for motivating students. According to the ARCS

Points	Description	Grading
1	The chapter is at least 2 pages long (double spaced 12-point font)	All or nothing
	Terminology	
3	The chapter includes the terms: asthenosphere	1 point - word, 2 points - correct use
3	continental volcanic arc	1 point - word, 2 points - correct use
3	convergent boundary	1 point - word, 2 points - correct use
3	core	1 point - word, 2 points - correct use
3	crust	1 point - word, 2 points - correct use
3	deep-ocean trench	1 point - word, 2 points - correct use
3	divergent boundary	1 point - word, 2 points - correct use
3	hot spot	1 point - word, 2 points - correct use
3	cithosphere	1 point - word, 2 points - correct use
3	mantle	1 point - word, 2 points - correct use
3	Moho	1 point - word, 2 points - correct use
3	plate boundaries	1 point - word, 2 points - correct use
3	plate tectonics	1 point - word, 2 points - correct use
3	plates	1 point - word, 2 points - correct use
3	spreading center or rift	1 point - word, 2 points - correct use
3	subduction zone	1 point - word, 2 points - correct use
3	transform boundary	1 point - word, 2 points - correct use
3	volcanic island arc	1 point - word, 2 points - correct use
	Tectonic Environment	
8	The chapter tells whether the park is near a plate boundary	All or nothing
8	The chapter correctly identifies the nearest type of plate boundary (passive margin, divergent, convergent, transform, or hot spot)	All or nothing
8	The chapter explains the basic nature of the plate boundary type	All or nothing
	Organization	
1	The introduction is a separate paragraph	All or nothing
1	The introduction tells the purpose of the chapter	All or nothing
1	The introduction describes the organization of the chapter	All or nothing
1	Headings show the separate sections	All or nothing
1	Related terms are presented together	All or nothing
1	Paragraphs are well-structured	All or nothing
1	Paragraph breaks are in appropriate places	All or nothing
1	Transitions explain relationships between paragraphs	All or nothing
1	The conclusion is a separate paragraph	All or nothing
1	The conclusion wraps up the chapter	All or nothing
1	The conclusion provides a transition to the next chapter.	All or nothing
5	The chapter is free of grammatical and spelling errors	5 points – no errors
		4 points – 1-2 errors
		3 points – 3-5 errors
		2 points – 6-8 errors
		1 point – 9 or more errors
	References	
1	The chapter includes in-text citations for unique information	All or nothing
1	The chapter includes a list of works cited	All or nothing
1	Web addresses and work titles are given	All or nothing
1	Authors are given	All or nothing
1	Publication dates and/or retrieval dates are given	All or nothing

Table 1. Example rubric for the Plate Tectonics chapter.

Bloom's taxonomy	Examples from student work
Knowledge	"The Cretaceous period began approximately 144 million years ago and ended approximately 65 million years ago lasting just around 79 million years." "The hydrologic cycle is composed of the following processes: evaporation, precipitation, runoff, transpiration, and infiltration."
Comprehension	"*During this time*, molten rock rose to a point just below the surface where it crystallized and would later become the Sierra-Nevada Mountains." [Italics added.] "After the water reaches the earth's surface, two things can happen. The water will either be soaked into the ground through the process of infiltration or it will flow to a water feature such as a river or a lake."
Application	"Evaporation takes place due to the rivers such as the Merced and the Tuolumne as well as the 3,200 lakes and two reservoirs that exist throughout the park."
Analysis	"The base level for running water in the Yosemite National Park is approximately 3,909 feet above sea level according to the topographical map. The elevations found in Yosemite can reach peaks of 8,000 feet above sea level with many drop off points containing waterfalls. These waterfalls provide a large amount of erosion power within the running water of the park."
Synthesis	"As you can see, the creation of an area such as Yosemite National Park is a very long and extensive process. It takes thousands if not millions of years just to make small changes in the appearance and geological profile of our planet. I hope after reading and studying this chapter, you will never look at a mountain or valley the same way again." "As you can see, the hydrologic cycle plays a major part in making Yosemite National Park what it is today. Without it we would not be able to enjoy most of the activities that people seek while at the park. After this chapter you should be able to give a clear definition to the term hydrological cycle with explanations for each of the processes that takes place."
Evaluation	"The Cretaceous period and the Cenozoic era were two very important intervals of time for the area of land we know today as Yosemite National Park."

Table 2. Examples of student work that support various levels of Bloom's taxonomy.

(Attention, Relevance, Confidence, Satisfaction) motivation model, relevance and satisfaction are two of the critical components to maintaining learner motivation (Keller, 1987). When the assignment is relevant to the learners, they are more likely to be motivated to learn the concepts. When learners are satisfied with (or proud of) their achievements, they are more likely to apply the knowledge in a new situation. Traditional tests typically lack relevance or satisfaction.

In the National Park guidebook project, students ended the semester with a product they could put on their personal bookshelf, which solved the problem of a lack of meaningful products. The project also created an immediate relevance for many of the objectives taught during class time.

KEYS TO SUCCESS

Designing a project like this was not without its pitfalls. After teaching three iterations of the Guidebook Project, I offer four keys to success with this project: detailed rubrics, prompt feedback, use of technology, and flexibility.

Most students are happy to create good work for their professors if they know what the professors expect. Clear expectations for the students are a critical part of a project like this. For each guidebook chapter, I created a detailed rubric that showed how all points were awarded. An example of the rubric for the Plate Tectonics chapter is included as Table 1.

For students to make use of suggestions, prompt feedback was imperative. Deadlines were on the same day every week. I blocked out time immediately after the deadline to evaluate student work. Grading was also prioritized; chapters with less time left for revision were graded before chapters with more time. Final drafts were graded last each week.

Several instructional technology innovations made the logistics of the project manageable. First, all drafts, including final drafts, were submitted and returned to students through WebCT, the online course management program. There were no papers to lose or damage. The documents to be graded were all in the same place and automatically backed up. Second, evaluation was done on a Notebook computer with a stylus. Using Microsoft Word's Ink Annotation capabilities, the student papers were marked up just as they would be with a pen. This also allowed me to keep copies of what had been suggested to students. Comments on previous drafts were available for review by the student and the professor. Reams of paper were saved with this use of technology.

Even with the technology, the grading process was time consuming. If the guidebook project were implemented in a class of 50 or more, grading assistance would almost certainly be necessary. Another strategy for managing the workload in a larger class is to have the students use the rubrics for self- and peer-review before the professor ever reads a draft.

The final key to success of an undertaking like this one is flexibility. Unforeseen circumstances, technology issues, and unrealistic expectations are common problems in implementing newly designed instruction. When these issues flared up, I strived for realistic, workable solutions that were in line with instructional goals.

EVALUATION

An important part of any instructional design project is evaluating it. The students' work and associated scores attested to the project's success at moving the learners into the more complex levels of Bloom's taxonomy. Table 2 shows statements from student work in two separate chapters that exemplifies the various levels of Bloom's taxonomy.

The final portion of the Guidebook Project asked students to reflect on their experiences throughout the semester. Feedback from the students supports the claims that the product is meaningful and learning occurred at a higher level. Some comments from student reflections are included below, and are used with Institutional Review Board approval.

- "Although the guidebook seemed like a pain to write, I feel proud to have finished the task at hand. It is nice to walk away knowing this is what I learned in geology."
- "I also enjoyed doing the topographic map as it was very hands on and made me start to feel a little like a geologist."
- "For most of the part, I enjoyed the guidebook project because it helped me learn a lot. It not only helped me to learn about [my park] or about the geologic features there, but other things like how to use the library and doing research or meeting deadlines."
- "It was definitely a new type of assignment that I am very proud of. I actually hope to visit the park I studied."
- "At times this project was confusing, frustrating, and the information wasn't always easy to find, but I learned to understand about the different topics rather than just memorizing them for the test."
- "Science has always been my hardest subject, but I actually enjoyed this class and am leaving it feeling like I learned a great deal, rather than walking out and feeling like I just memorized a ton of stuff that I didn't really understand."

Of course, there was some negative feedback as well. The most common complaint students had was about the workload. Some also were confused or overwhelmed by the multiple deadlines for each chapter. Future iterations of the project will include adjustments in these areas.

CONCLUSION

Research in the psychology of learning supports the importance of meaningful products, higher levels of learning, and the correction of misconceptions. The National Park Geologic Guidebook project is an inquiry-based project that helped students do all these things. With detailed rubrics, good technology, a commitment to prompt feedback, and an attitude of flexibility, the project can be manageable for the professor as well.

Since implementing the guidebook project, I finish each semester feeling confident that students got their money's worth from the class. Students will think about geology when they visit the park they researched. They take away a concrete, relevant, coherent product from their semester in physical geology.

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