AC 2010-1398: A HANDS-ON APPROACH TO GEOLOGY FOR ENGINEERS

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Geology by touch: the first iteration of integrating overarching examples and laboratories into an introductory geology class

Abstract

All civil engineering students at Villanova University are required to take geology in their sophomore year. About one half of the course is devoted to historical geology and the other half is devoted to physical geology. In the past, the class has been lecture-based with four laboratories throughout the semester. In the fall of 2009, a plan was implemented to build upon the existing strengths of this course, which include well-developed and assessed information literacy modules, by creating additional hands-on laboratories and three over-arching examples to place the content into context. The additional laboratories and the over-arching examples will be described in this paper. The effectiveness of this plan was assessed using student work and via an attitudinal survey conducted at the end of the semester. These assessments, as well as the observations of the professor, indicate that the plan did yield some improvement in student learning; however, several modifications are needed when the class is taught again.

Introduction

Karl Terzaghi, widely regarded as the father of soil mechanics once said, "In soil mechanics the accuracy of computed results never exceeds that of a crude estimate, and the principle function of theory consists of teaching us what and how to observe in the field."[1] This quote drives home the point that civil engineers, and anyone else that works at the interface of the natural and built environment, needs to understand geology. Because of the importance of geology to civil engineering, GLY 2805 Geology for Engineers is a required sophomore-level course in civil engineering at Villanova University. Although the course is predominately civil engineering students, often environmental studies and geography students enroll as well.

Villanova University is the largest Catholic university it the state of Pennsylvania with over 10,000 undergraduate and graduate students. Villanova was founded by the Order of Saint Augustine in 1842 and is located about 15 miles west of Philadelphia. There are approximately 900 students in the College of Engineering; the Civil and Environmental Engineering Department graduates between 40 and 65 students per year. The university and the college are well ranked by US News and World report. For example, amongst master's level universities, Villanova was ranked #1 in the Northeast and the college of engineering was ranked #10[2].

In the past, GLY 2805 Geology for Engineers has been taught in a fairly traditional format dominated by lecturing on physical and historical geology with four laboratories. An analysis of prior student assessments revealed that students were performing well on the student work assessed in this course, but that they often described the class as "boring." While boredom may not be the most compelling reason to change a course, it is important to note that this course comes at a pivotal time in a student's education: first semester of sophomore year. This course helps set the tone for the remaining three years the students will spend in their major and, as such, it is an opportunity to spark interest in the sub-disciplines of geotechnical, water resources, and environmental engineering. The changes implemented in this course also compliment a shift

to more active-learning based approaches[3] used throughout the curriculum[4]. Consequently, the goals of the changes to the course described in the paper were to:

1. Improve student learning
2. Improve student interest and attention
3. Align the course structure with other courses within the department's curriculum

This paper will focus on the data collected in support of the first two goals by examining student work assessed as part of the ABET assessment process, comparing performance on selected multiple choice questions, as well as soliciting student opinions on the changes via a survey conducted at the end of the semester.

Placement in the Curriculum and Relationship to Our Educational Outcomes

GLY 2805 Geology for Engineers is taught by the faculty of the Department of Civil and Environmental Engineering. It is a prerequisite for one course, CEE 3801 Soil Mechanics. As mentioned previously, it is typically taken in the fall of sophomore year. The material taught in this course supports achievement of the following educational outcome "…graduates of the Department of Civil and Environmental Engineering will be able to explain and apply selected principles from basic and applied sciences to solve common engineering problems." This departmental-specific outcome encompasses ABET program criteria 3a) an ability to apply knowledge of mathematics, science, and engineering and the program-specific criteria developed by ASCE that states that the program must demonstrate that graduates can apply knowledge of … at least one additional area of science, consistent with the program educational objectives[5]. Student work from this class is used to assess how well our students are achieving this outcome.

Course Outcomes

The course outcomes for GLY 2805 are:

1. Explain selected basic topics in physical geology, particularly those that affect civil engineering practice.
2. Explain how geologic processes and their attendant landforms can influence aspects of engineering design including site development.
3. Refine skills associated with professional engineering practice including research and written communication.

Course Content

The plan described in this paper seeks to build upon the strengths of this course to create a course that is engaging and meaningful to the students (and the faculty member teaching it). The major strengths of the course before modifications were: four hands-on laboratories, a well-developed and assessed information literacy module with a term-paper as the final product[6,7], and on-going student presentations on current geologic issues. The time spent in this class could be broadly divided into three categories: technical (lecture) topics, professional development and information literacy, and laboratories (Table 1).

Table 1. Topics in GLY 2805 Before Modification

Lecture (Technical) Topics	**Professional Development and Information Literacy**	**Laboratories**
Origins of the Earth		
	Evaluation of Websites	
Plate Tectonics		
	Searching for and Using Sources	In-library Session
Minerals		Mineral Identification
Igneous Rocks		
Volcanoes and Volcanism		
Weathering, Erosion, and Soil		
Sediment and Sedimentary Rocks		
Metamorphism and Metamorphic Rocks		Rock Identification
Geologic Time		
Earthquakes		Seismograms
Deformation		
	The Curriculum, the Body of Knowledge, and the Profession	
Mass Wasting		
Lakes and Streams		
Groundwater		
Glaciers and Glaciation		
The Work of Winds and Deserts		
Shorelines and Shoreline Processes		
Landforms		Landforms

Active Learning Techniques

Kathleen McKinney defines active learning as "techniques where students do more than simply listen to lecture."[8] She describes several techniques that are classified as active learning, two of which are case studies and collaborative learning groups.[8] The changes to GLY 2805 attempted to stimulate active learning by using three over-arching examples as the case studies and additional laboratories as a means to foster collaborative learning groups. Laboratories were selected for expansion because previous student feedback indicated that the laboratories were an enjoyable part of the course that enabled the students to apply the material taught in lecture. Thus, the plan was to move some of the content taught in the first column of Table 1 to the last column of Table 1. In addition, to place the content of this course into context, three over-arching examples were developed[9].

Over-arching Examples

Example One: The Geology of Southeastern Pennsylvania

The geology of southeastern Pennsylvania, and more specifically, the Village of Valley Forge, was used as the backdrop for the topics covered in the first half of the class. The Village of Valley Forge is a site currently under development near Villanova's campus in King of Prussia, Pennsylvania near the King of Prussia Mall and Valley Forge Park (http://villageatvalleyforge.com). A field trip to Valley Forge Park led by a geologist from the Pennsylvania Geological Survey was part of this unit. This example provided the context for the following topics:

- Origins of the Earth
- Plate Tectonics
- Minerals
- Weathering, Erosion, and Soil
- Igneous Rocks
- Sediment and Sedimentary Rocks
- Metamorphism and Metamorphic Rocks
- Geologic Time
- Deformation

Example Two: The Ogallala Aquifer

The example used to put the geological concepts into context was the Ogallala Aquifer, which is also known as the High Plains Aquifer. The topics taught were:

- Plate Tectonics
- Geologic Time
- Deformation
- Running Water
- Groundwater
- Glaciers and Glaciation
- The Work of Winds and Deserts

Example Three: The Great Tsunami of 2004

This tsunami, which devastated Indonesia, Sri Lanka, India, and Thailand, was responsible for over 200,000 deaths. Disasters make for gripping examples; this example provided a platform to study the following topics:

- Plate Tectonics
- Volcanoes and Volcanism
- Earthquakes
- Mass Wasting
- Shorelines and Shoreline Processes

Additional Laboratories

Laboratories provide the students with a hands-on learning opportunity. In the past, there were four laboratories associated with this class. Two additional full laboratories and three additional half-class laboratories, for a total of nine laboratories were planned for the Fall 2009[9]. Ward's GEO-Logic System Topic sets (available from Ward Science, http://wardsci.com) were used for

the Igneous, Sedimentary, and Metamorphic Rocks; Streak, Color, and Luster; Hardness; Cleavage, Fracture, and Parting; and Crystal Form and Tenacity. The planned laboratories were:

- Igneous Rocks
- Sedimentary Rocks
- Metamorphic Rocks
- Rock Identification
- Streak, Color, and Luster
- Hardness
- Cleavage, Fracture, and Parting
- Crystal Form and Tenacity
- Mineral Identification
- Seismograms
- Landforms

The implementation of the additional laboratories was not as successful as the over-arching examples. The mineralogical laboratories that were intended to be half laboratories (Hardness; Streak, Color, and Luster; Cleavage, Fracture, and Parting; and Crystal Form and Tenacity took over four class periods to complete. This prevented the class the performing the Mineral Identification and Landforms laboratories, which was a serious loss to the course.

Assessment

The effectiveness of these changes was assessed using student work, attitudinal data, and the instructor's observations. It is important to note that GLY 2805 was not a dysfunctional course as reflected by previous student evaluations and student work collected as part of our ABET assessment process[10]. For example, student evaluations for such items as "rate the overall value of this course" and "rate overall quality of instruction" have fluctuated between 3.1 and 3.9 out of 5.0 over the past five years. Adequate course evaluations should not be an impediment to implementing improvements, however.

The author teaches this course every other year, so student work from 2007 and 2009 were compared to ascertain the effectiveness of the changes implemented. The data collected from these two groups of students are comparable because the class size was similar (60 in 2007 and 62 in 2009), the same text book was used[11], the professor was the same, the class was held in the same location, and the class composition was similar in regards to average GPA (2.80 in 2007 and 2.87 in 2009) and gender mix (26% in 2007 and 27% in 2009).

Selected exam problems are used to determine if students can apply their knowledge of geology as part of our ongoing assessment process[10]. The student work is placed into five categories: complete mastery of the concept with no errors, mastery of the concept with minor errors, satisfactory attainment of the concept with some errors, limited attainment of the concept with multiple errors, and unsatisfactory attainment of the concept with many grave errors. In both 2007 and 2009 the students were asked a series of question about the formation of karst terrane. Specifically, in 2007 the students were asked:

- One of our guest speakers explained how karst topography can form next to a valley. He drew a sketch similar to the one below (Figure 1). Explain how this cavity was formed in terms of weathering processes, including the chemical reaction.

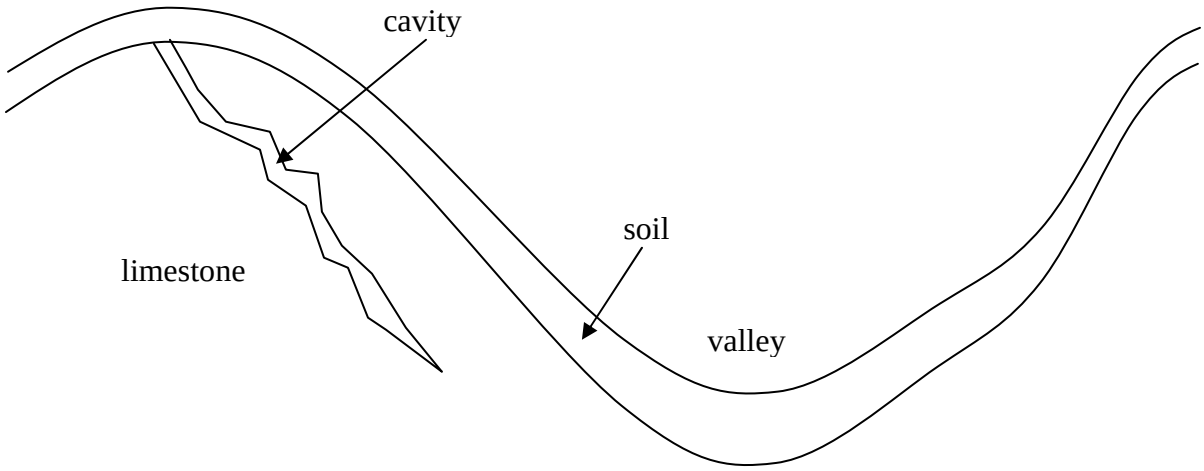

Figure 1. Exam problem from 2007

In 2009, the students were asked a similar question about the formation of karst below the Village at Valley Forge development. The students were provided an aerial photo of the site as well as the geologic map of Pennsylvania. Specifically, the students were asked:

- Explain the roles of plate tectonics, deformation, and weathering in the formation of sinkholes in this area. Explain, using chemical equations, how sinkholes form.

A summary of the assessment results from 2007 and 2009 is provided in Table 2.

Table 2. Comparison of Student Work

	2007	2009
Complete mastery of the concept with no errors	0%	22%
Mastery of the concept with minor errors	23%	18%
Satisfactory attainment of the concept with some errors	57%	29%
Limited attainment of the concept with multiple errors	17%	21%
Unsatisfactory attainment of the concept with many grave errors	3%	10%
% at satisfactory or above	80%	69%

The results of the student work assessment do not paint a clear picture of the effectiveness of the changes. While more student work was rated at the mastery level or above in 2009 as compared to 2007 (40% versus 23%), more student work was rated at limited or below in 2009 as compared to 2007 (31% versus 20%).

In addition to the student work assessed as part of our ongoing assessment efforts, three multiple choice questions were used in quizzes and tests in 2007 and 2009. A comparison of the percentage answering each question correctly is provided in Table 3. The correct answer to each

question is shown in bold type. The percentage of students answering the questions correctly in 2009 was slightly higher than in 2007, which indicates some improvement in student learning.

Table 3. Comparison of Three Multiple Choice Questions

Question	2007	2009
Chemical weathering is most effective in which combination of conditions? a. cold and arid **b. warm and humid** c. warm and arid d. humid and seasonal e. cold and humid	83.3	84.4
Current production of groundwater from the High Plains Aquifer cannot be sustained because a. the small farmer is increasingly not viable **b. recharge is less than discharge** c. discharge is less than recharge d. global climate is warming because of human impacts e. irrigation will decrease in the future	88.1	88.1
The magnitude of an earthquake is another term for a. its intensity b. the damage created **c. the energy released** d. the duration of trembling	80.7	88.5

To obtain attitudinal information the students were asked the following two questions at the end of the semester:

- During the semester we focused on three over-arching examples. The first was the geology of southeastern Pennsylvania, the second was the Ogallala aquifer, and the third was the 2004 Tsunami. Did the use of these examples help you learn the material? Do you have any suggestions for improvement?
- During this semester we did many laboratories. Did the use of the laboratories enhance your understanding of the material? Please provide any suggestions for improvement.

The students received extra credit for answering the two questions. There was a 100% response rate. The responses were read and divided into two categories: yes and no (Table 4). The suggestions for improvement were also analyzed and are discussed in the next section.

Table 4. Results of Student Survey

	Did the use of these examples help you learn the material?	Did the use of the laboratories enhance your understanding of the material?
Yes	79%	64%
No	21%	36%

Lessons Learned and Improvements for Next Time

The author will teach GLY 2805 again in Fall 2011. As can be expected, not all of the changes made in Fall 2009 were successful. The new format of the course based on the assessed student work and the survey is presented in Table 5. The session on The Curriculum, the Body of Knowledge, and the Profession will be moved to another class because of other curricular changes.

Over-arching Examples

The student responses, which were similar to the author's observations, indicate that the over-arching examples were better received than the additional laboratories. The student work evaluated also suggests that there was some improvement in student learning. The suggestions for improvement from the students were inconsistent: ranging from abandoning the over-arching examples to having more. However, when the suggestions from the students that felt the examples were useful were examined some common themes emerged. These themes are to:

- Develop the case studies more
- Retain the field trip to Valley Forge Park

Some of the topics did not fit well into the selected over-arching examples, consequently, the examples will be broadened to better accommodate the course material as reflected in Table 5.

Laboratories

The student responses once again were generally in agreement with the author's observations on the effectiveness of the laboratories and the evaluated student work did show some improvement. The laboratories on sedimentary, igneous, and metamorphic rocks, rock identification, and seismograms were useful. The additional laboratories on mineralogy (Hardness; Streak, Color, and Luster; Cleavage, Fracture, and Parting; and Crystal Form and Tenacity) required too much class time and did not greatly improve student learning. These laboratories will be removed, allowing enough time to complete the scheduled laboratories on landforms and mineral identification. The removal of the additional laboratories on mineralogy will also allow more time to cover material related to the case studies.

Conclusions

Two major changes were implemented in a sophomore-level required geology class in Fall 2009. The effectiveness of these changes was evaluated using student work and surveys; the author's observations on the effectiveness of these changes are in agreement with the student responses. The results of the student work assessed were mixed: more students performed at the mastery level and above as well as at the limited and below category after the changes were implemented. Three multiple choice questions that were used on tests and quizzes in both years did show a slight improvement in the percentage students answering correctly. The student surveys provided more feedback. This feedback, as expected, was also mixed, however, some general trends could be ascertained from the data. The student surveys and the instructor's observations indicate that the over-arching examples were more effective in increasing student learning than the additional

laboratories. Some of the additional laboratories required too much class time that could be better spent further developing the over-arching examples.

Table 4. Restructured Course Plan for GLY 2805 for Fall 2011

Over-arching examples	**Lecture (Technical) Topics**	**Laboratories**	**Information Literacy**
Geology of Southeastern Pennsylvania	Origins of the Earth		
	Plate Tectonics		Evaluation of Websites
		In-library Session	Searching for and Using Sources
	Geologic Time		
	Minerals		
		Mineral Identification	
	Igneous Rocks	Igneous Rocks	
	Weathering, Erosion, and Soil		
	Sediment and Sedimentary Rocks	Sedimentary Rocks	
	Metamorphism and Metamorphic Rocks	Metamorphic Rocks	
		Rock Identification	
		Field Trip	
Geology of the Western United States	Plate Tectonics, Geologic Time, Deformation		
	Glaciers and Glaciation		
	Lakes and Streams		
	Groundwater		
	The Work of Winds and Deserts		
	Mass Wasting		
	Shorelines and Shoreline Processes		
			Landforms
Great Tsunami of 2004	Volcanoes and Volcanism		
	Earthquakes		
		Seismograms	

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