2018 ASEE Annual Conference & Exposition
Paper ID #22096

Strategies for Flipping Geology for Engineers with Limited Time and Resources

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Abstract

Civil, environmental, and/or architectural engineers are often required to take a geology course as part of their undergraduate curriculum. In the past, engaging and interesting engineering students in geology at Villanova University and Drexel University has been a challenge. Therefore, the authors collaborated to overhaul their respective geology courses with the goals of improving student engagement, learning, and satisfaction. Based on literature supporting the potential benefits of a flipped (inverted) classroom, as well as previous success by other faculty at Villanova University in flipping other required engineering courses, the authors decided to change geology from a mostly lecture format to a flipped classroom format. However, the time and resources required to convert a course to a flipped format can quickly become overwhelming, especially for tenure-track faculty. Nonetheless, the authors were able to successfully, and efficiently, flip their geology courses by utilizing several simple strategies that leveraged free, existing resources. Comparison of student evaluation scores from previous years (lecture format) with the newer flipped format as well as student surveys indicated improved student perception of use of class time, instructor interaction, amount learned, how intellectually stimulating the course was, quality of instruction, and overall value of the course to their education. The strategies used to flip the geology course with limited time and resources are useful for other engineering courses as well, and are described in detail. Challenges encountered with implementing the new format at both universities also are discussed.

Introduction and Background

At many universities, undergraduate students enrolled in civil, environmental, and/or architectural engineering programs are required to take a basic geology course. At Villanova University, Geology for Engineers (CEE 2805) is required for all Civil and Environmental Engineering students. Similarly, at Drexel University, Geologic Principles for Infrastructure & Environmental Engineering (CAEE 212) is a required course for all civil, architectural and environmental engineering students. At Villanova, the three-credit class meets twice a week for 75 minutes and is taught in two sections with approximately 30 students in each section. At Drexel, the four-credit class meets twice a week for 80 minutes and once a week for two hours (including a laboratory portion) as one large section. The class size at Drexel typically ranges from 60 to 80 students, but the last offering (fall 2017) had an abnormally low enrollment of 34 students. Although the academic calendar at Drexel is on a quarter system and Villanova is semesters, the number of class meetings is essentially the same for both schools. For both universities, the geology course fulfills a science requirement for ABET.

In the past, engaging and interesting engineering students in geology at both universities had been a challenge. Despite the authors' best efforts, students struggled to appreciate the relevance of basic geology to engineering. When teaching the course in a mostly lecture-style format, the authors were constrained in the amount of activities and examples they could include to emphasize the link to engineering, while still covering all of the basic geology content that was required. Literature supporting the potential benefits of a flipped (i.e. inverted) engineering classroom, e.g. [1-12] , as well as previous success by other faculty at Villanova University in flipping required civil engineering courses [13, 14] motivated the authors to overhaul geology from a mostly lecture format to a flipped classroom format. A flipped class typically involves delivering course content via readings or online lectures outside of class. In class, active learning strategies are employed so students apply key concepts and are able to get feedback. In this case, most course content was delivered using online videos or narrated PowerPoint lectures outside of class, with short in-class lectures to highlight key points and engineering applications of geology. The majority of class time was interactive, with students doing a variety of activities in small groups while the instructor circulated around the room providing feedback.

The time and resources required to convert a course to a flipped format can be daunting. The initial effort may be overwhelming, especially for tenure-track faculty and without outside support. However, the authors were able to utilize some simple strategies to maximize efficiency in changing their respective geology courses from what had been mostly lecture format to a flipped format that was first implemented in fall 2016. At the time of this paper, the flipped format has been in place for two years and student and faculty feedback regarding the change has been positive. The reader should note that the purpose of this paper is *not* to assess the impact of the flipped classroom on student learning. Rather, this paper describes simple strategies and free resources that were used to flip the course, which may be useful for flipping other courses, and provides specific examples of how the flipped geology course was structured.

Strategies Used

The authors collaborated to flip their geology courses at both universities, with the goals of improving student engagement, learning, and satisfaction. The courses were successfully, and efficiently, overhauled by utilizing some simple strategies and free, existing resources. These strategies (or “tips”) are described in detail subsequently.

Tip 1. Partner with a colleague

If possible, partner with a colleague at another (or the same) university who wants to flip a similar course and also has a similar degree of investment in a successful outcome. There are two very important benefits of working with someone else on this endeavor. First, you can divide and conquer. The authors at each university prepared materials for about half of the 25 class periods, which included pre-class materials and in-class activities. Topics were divided based on areas of expertise where possible or instructor availability at the time the materials were needed. In this case, the first author received an educational grant to support development of the revised course and the second author revised the course during sabbatical leave. As a result, the authors had a relatively equal investment in achieving a successful outcome and participated equally in course development.

Flipping a course typically requires cutting some content. Thus, the second major advantage of partnering with someone is the ability to discuss with and agree upon the *most* important outcomes for the course. The authors wanted the course to better engage students in learning geology, so decided to focus on the engineering relevance of geology to civil, architectural and environmental engineering. In addition, the course is a prerequisite for subsequent geotechnical engineering courses, so another goal was to spark student interest in geotechnical engineering to potentially increase enrollments in upper level courses.

The resulting course was a combination of introductory physical geology, rock mechanics, and geomorphology. Table 1 is an example topic schedule for the revised course. A basic understanding of Earth's structure and tectonic processes is necessary to understand how Earth works and the various environments in which rocks form. Additionally, a general understanding of the rock cycle, minerals, and major rock classes is required to understand how different rocks behave in various engineering applications.

Table 1. Example topic schedule for flipped geology class at Villanova and Drexel Universities.

Major Topic	**Topic No.**	**Topic**
Earth Structure & Plate Tectonics	1	Course intro
	2	Earth system & plate tectonics
	3	Geologic time
Rock Cycle & Rock Types	4	Minerals & the rock cycle
	5	Mineral identification
	6	Energy & mineral resources
	7	Volcanic Processes
	8	Igneous rocks
	9	Sedimentary rocks
	10	Metamorphic rocks
	11	Rock identification
Rock Mechanics, Structural Geology, Earthquakes & Hazards	12	Weathering & soil
	13	Rock mechanics
	14	Structural geology & earthquakes
	15	Earthquake engineering
	16	Landslides
Geomorphology	17	Landscapes & hydrologic cycle (***campus tour***)
	18	Streams & floods
	19	Groundwater
	20	Field trip (***self-guided***)
	21	Geophysical methods & karst
	22	Glaciers & glacial landforms
	23	Oceans, coasts & climate change
	24	Rating systems for sustainable engineering

The second half of the term is devoted to introductory rock mechanics, geologic hazards, and introductory geomorphology. Rock mechanics includes stress-strain behavior of rocks and an introduction to rock mass rating systems. Geologic hazards such as earthquakes and landslides are covered next, and geotechnical resources (e.g. GEER reports, USGS design maps) are utilized in the activities. In geomorphology, the topics include the interaction of the lithosphere with the atmosphere, hydrosphere, and biosphere and the landforms that result from those interactions. Throughout the course, the activities deliberately focus on the engineering aspects or applications of geology.

Tip 2. Decide on course layout and logistics upfront
The authors learned not to underestimate the importance of course organization and thorough logistical planning to successfully teach in a flipped format. There were important questions about the course that the authors found useful to reflect upon *before* attempting to adapt/develop any materials for the new format. For example:

1) What types of content and learning outcomes should the students be responsible for outside of the classroom versus in the classroom? How and when will that content be delivered?
2) Should the entire class period be devoted to active learning or would the students benefit from starting with a brief (e.g. 10-15 minute) lecture first to review important or challenging concepts, prior to transitioning to activities for the remainder of the class time?
3) Will the students be tested on (e.g. online or in-class quizzes) or otherwise held accountable for pre-class content, prior to starting the in-class session?
4) How will the various components (watching videos, pre-class quizzes, in-class activities, etc.) "count" toward their final course grade?

Considering these types of details upfront helped the authors lay out and develop the materials for the whole course, with consideration of the different logistical constraints at each university. In the new flipped format at Villanova and Drexel, students watch and/or read assigned materials prior to covering the topic in the classroom, such that classroom time is devoted to group discussions and activities that emphasize application of basic geology concepts to civil and environmental engineering problems. Course information is listed on Blackboard, including recorded lectures, lecture notes, quizzes, handouts, and assignments. Each topic (#1 through 24) is organized into parts "A" and "B", as shown in Figure 1.

Figure 1. Example structure used in flipped geology course at Villanova and Drexel Universities.

A. Pre-Class: Guided Exploration of Essential Geology Concepts		***B. In Class: Engineering Applications & Active Learning***	
Pre-Lecture Videos (on Blackboard)	**Video Quiz** (on Blackboard)	**Concept Review & Engineering Examples** (very brief lecture)	**Active Learning** (group work)
Typical Outcomes: Remember, Understand, Explain, Classify		Typical Outcomes: Apply, Analyze, Evaluate, Compare, Create	

Folder "A" includes materials that should be completed before class, and "B" includes material covered during the class period, including activities and assignments. Students are responsible for all material covered in both the "A" and "B" portions of the course. Pre-class materials are posted at least two days in advance to allow students adequate time to access and review the content. The on-line quizzes are automatically graded in Blackboard (with a deadline set to the class start time) and students are able to review their scores. When needed, a brief (e.g. 10-15 minute) lecture is provided at the start of the in-class session to review important concepts from pre-class materials or introduce challenging concepts required for the activity that day. The in-class activities (which typically are done in groups) are due by the end of class or by the start of the next class, and are graded and returned the following week. For Villanova and Drexel, grading of all activities was feasible because there were graduate student graders allocated to the course.

Tip 3. Utilize existing high-quality resources

Preparing pre-class and in-class activities requires a significant investment of time and effort. Given the demands of an academic schedule and the rapid pace at which a term unfolds, it is imperative to be strategic about developing course materials. Therefore, the authors recommend utilizing existing resources to the extent possible. This will enable one to devote the bulk of available time to developing materials for which no resources exist or modifying existing materials to introduce nuances that are specific to the new course.

When the authors began this course revision, they discovered that geoscience faculty and textbook providers have already developed an assortment of high-quality introductory geoscience videos as well as a vast array of geoscience activities on a wide variety of topics. For each topic covered, if the authors didn't already have the materials to implement the flipped format, time was taken to search available resources. This practice saved significant effort and resulted in a higher quality course. It is important to emphasize that existing materials must be of high quality in order to be utilized.

Pre-class videos: There were numerous benefits to adopting this approach for pre-class lecture videos. First and foremost, many of the available online videos were extremely well done. For example, some educators have previously received grants to professionally produce introductory geoscience videos (e.g. GeoScience Videos, https://geosciencevideos.wordpress.com). Additionally, textbook providers may have resources available to produce high-quality videos. In these videos, geoscience experts distill the most important information into short (e.g. < 10 min), effective, interesting and accessible segments. They are typically of a higher quality than the authors could produce, which was largely narrated PowerPoint presentations. Second, and most relevant to this paper, the use of existing videos was much more efficient than developing new videos. Third, the combination of videos recorded by other geoscience educators and the authors' own recorded videos provided a good variety of presentations that helped to keep students engaged. Finally, the practice of utilizing existing resources when possible enabled the authors to spend more time developing their own high quality presentations. In particular, the authors recorded their own videos (using Microsoft PowerPoint add-in, Office Mix) to focus specifically on topics related to civil or environmental engineering aspects of geology.

In-class activities: Where possible, existing homework assignments and laboratory exercises from previous offerings of the course were modified and incorporated into the new course structure. These activities covered about one-third of the topics. For the balance of the activities, online databases were used when possible. For example, many activities related to physical geology, geomorphology, and energy and mineral resources are available from the Science Education Resource Center at Carleton College (SERC http://serc.carleton.edu). Activities related to soil mechanics are available through the United States Universities Council on Geotechnical Education and Research (USUCGER, http://www.usucger.org/). The activities were modified as necessary to fit the learning objectives for the particular topic of interest. Finally, remaining time was used to develop new activities for the remainder of the topics. As noted above, this approach enabled the authors to more efficiently flip the course.

Tip 4. Use familiar technology

For recording pre-lecture videos, new software can be expensive and require a significant initial time investment if one is unfamiliar with using it. For the first iteration of flipping a course, the authors preferred starting with software and resources they were already familiar with and that required limited (to no) financial investment. The pre-lecture videos for geology at Villanova were easily edited and recorded with Office Mix, a free add-in for Microsoft Office PowerPoint and with TechSmith Relay, a lecture capture add-in available at Drexel. As these tools were part of PowerPoint, a format that the authors already had extensive experience in, there was little to no time commitment required for learning new software. In addition, PowerPoint lecture presentations from previous years could be used as a starting point for the video materials.

The authors also utilized their existing course platforms (Blackboard) to post video lectures and pre-class quizzes based on the videos. To avoid the additional load of grading pre-class quizzes that were part of the new flipped format, all quizzes were automatically graded and recorded within Blackboard. Students were able to review their scores for immediate feedback and were allowed a second quiz attempt.

Finally, the authors were able to optimize the time required for development and implementation of new in-class activities by including tools they were already familiar within the assignments. For example, the activity for topic 23 requires students to quantify coastal vulnerability due to sea level rise, using a Microsoft Excel worksheet (adapted from SERC http://serc.carleton.edu). For topic 16 (landslides), the students virtually explore the 2014 slide in Oso, Washington, using Google Earth.

Feedback Regarding Course Format

Student feedback

Student feedback regarding the new course format at both universities has been positive. An anonymous survey was administered on the last day of class in fall 2017 at both Villanova and Drexel. The purpose of the survey was to ask students about their learning experience and their perceived effectiveness of the course format. The survey questions are provided in Table 2. The answer choices were: strongly disagree (1), mildly disagree (2), neutral (3), mildly agree (4), and strongly agree (5). At Villanova and Drexel a total of 47 and 30 students completed the surveys (92 % and 88 % response rates), respectively.

Table 2. Summary of student survey results collected on the last day of the course in 2017.

Survey Question	**Average Score (out of 5)**			**% that Responded Mildly or Strongly *Agree***		
	Villanova Univ.		Drexel Univ.	Villanova Univ.		Drexel Univ.
	Section 1	Section 2		Section 1	Section 2	
1. I feel that the format of this course improved my overall learning over a classical in-class lecture format.	3.8	4.2	4.3	68.4	85.7	90.0
2. I feel that the format of this course required a reasonable investment of my time (relative to a classical in-class lecture format).	3.8	3.9	4.5	68.4	67.9	96.7
3. I feel that the format of this course improved my ability to apply basic geology knowledge over a classical in-class lecture format.	4.0	4.4	4.3	73.7	92.9	83.3
4. I feel that the format of this course allowed me to interact directly with the instructor more than in a classical in-class lecture format.	3.9	4.1	4.6	68.4	75.0	90.0
5. For this geology class, I prefer this course format over a classical in-class lecture format.	3.6	4.3	4.1	57.9	85.7	73.3
6. The in-class activities improved my understanding of basic geology.	4.3	4.7	4.5	89.5	92.9	96.7
7. The in-class activities improved my understanding of the relevance of geology to civil engineering.	4.4	4.6	4.4	89.5	96.4	90.0
8. The in-class activities provided real-world context for the topics covered.	4.6	4.6	4.4	94.7	100.0	90.0
9. I watched most (at least 85 %) of the lecture videos.	4.3	4.5	3.5	78.9	82.1	50.0
10. I have gone back to re-watch lecture videos to better understand a topic or study for an exam.	4.1	3.8	4.0	78.9	64.3	73.3
11. The exams and quizzes were fair.	4.2	4.6	3.8	73.7	96.4	66.7
12. After taking this course, I am more interested in how rock, soil, water, and climate play roles in civil engineering infrastructure.	3.8	4.1	4.0	68.4	75.0	76.7
Total Number of Survey Responses Received	19 (86 %)	28 (97 %)	30 (88 %)	19 (86 %)	28 (97 %)	30 (88 %)

As shown in Table 2, the feedback from the students regarding the new flipped format was quite positive. Not surprisingly, most of the students (68 – 75 % of Villanova students, and 90 % of Drexel students) agreed the flipped format allowed them to interact directly with the instructor more than in a classical lecture format (question # 4). The most positive feedback from the students was regarding the value and effectiveness of the in-class activities. More than 90 % of the students at both universities felt that the in-class activities improved their understanding of basic geology (question # 6) and the relevance of geology to civil engineering (#7), and provided real-world context for the topics covered (question # 8). The authors suspect that the success of the in-class activities contributed to most (68 – 77 %) of the students saying they were more interested in how rock, soil, water, and climate play roles in civil engineering infrastructure after taking the course (question # 12). An interesting observation is that although not all students were diligent about watching the pre-class videos (question # 9), 64 to 79 % of the students reported taking advantage of the ability to re-watch videos prior to exams (question # 10).

For the geology course at Villanova, data from the official university Course and Teacher Surveys (CATS) collected before and after implementing the flipped format were compared. A total of 29 questions were included in the CATS, which were distributed to the students on the last day of the course each year. Of those, eight questions were selected as the most pertinent to assess the students' view of the traditional versus flipped format and their learning experience (i.e. unrelated questions about the classroom facilities, etc., were excluded). The questions and results are summarized in Table 3. Answer choices ranged from strongly disagree (1) to strongly agree (5). Results from 2015 are from before implementation of the flipped format, whereas results from 2016 and 2017 are after implementing the changes. Data prior to 2015 is not included because there was a different instructor. Also, data from the two sections were kept separate to improve comparison between years as, historically, more high-achieving students typically enroll in the second section than the first. Data from Drexel course evaluations is not included because of low response rates (< 25 %).

Based on questions 1, 2, and 3 in Table 3, after implementing the flipped format the students reported a significant (12 - 41 %) increase in perceived effectiveness of use of class time, instructor interaction, and encouragement to participate. Interestingly, although the students felt they learned more in the flipped format (question 6; score increased 18 - 41 %), they did not feel they worked "harder" (question 4; decreased 0 - 6.8 %), which may suggest the flipped format better allowed for flexibility of learning styles and timely, formative feedback to aid learning. From the results from questions 5, 7, and 8, after implementing the flipped format the students reported that they found the course more intellectually stimulating, they perceived the quality of instruction as higher (note the same instructor taught all three years), and they felt the course had higher overall value to their education.

Table 3. Comparison of CATS scores for Geology for Engineers at Villanova prior to (year 2015) and after (years 2016 and 2017) implementing the flipped course format.

	Question	Course Mean: Before Flipping	Course Mean: Flipped Format		Change from 2015 to 2017 (%)[1]
		2015	2016	2017	
Section 1	# of Responses (% of enrollment)	19 (73 %)	24 (83 %)	20 (91 %)	-
Section 1	1. The instructor for this course uses class time effectively.	4.0	4.4	4.7	+18
Section 1	2. The instructor for this course interacts effectively with the students.	4.1	4.7	4.6	+ 12
Section 1	3. The instructor for this course encourages student participation.	3.9	4.8	4.8	+ 23
Section 1	4. Hard work is required to get a good grade.	4.4	4.2	4.1	- 6.8
Section 1	5. I found the course intellectually stimulating.	2.9	4.0	4.3	+ 48
Section 1	6. I learned a great deal in this course.	3.2	4.2	4.5	+ 41
Section 1	7. Rate the overall quality of instruction in this course as it contributed to your learning.	3.9	4.5	4.5	+ 15
Section 1	8. Rate the overall value of this course to you as it contributed to your learning.	3.1	4.2	4.3	+ 39
Section 2	# of Responses (% of enrollment)	26 (87 %)	28 (97 %)	28 (97 %)	-
Section 2	1. The instructor for this course uses class time effectively.	3.4	4.6	4.8	+ 41
Section 2	2. The instructor for this course interacts effectively with the students.	3.8	4.8	4.7	+ 24
Section 2	3. The instructor for this course encourages student participation.	4.1	4.6	4.9	+ 20
Section 2	4. Hard work is required to get a good grade.	4.1	4.0	4.1	0.0
Section 2	5. I found the course intellectually stimulating.	3.7	4.3	4.4	+ 19
Section 2	6. I learned a great deal in this course.	3.9	4.2	4.6	+ 18
Section 2	7. Rate the overall quality of instruction in this course as it contributed to your learning.	3.5	4.7	4.6	+ 31
Section 2	8. Rate the overall value of this course to you as it contributed to your learning.	3.8	4.3	4.5	+ 18

[1]Calculated as: 100 % x (2017 score – 2015 score) / 2015 score

This feedback has encouraged the authors to continue with the flipped format in future years. A thorough assessment of the impact of the new format on actual student learning and retention of material is beyond the scope of this paper. Administering simple student surveys similar to that summarized in Table 2 is a useful, quick tool to gauge students' learning experience and perception of the efficacy of the new format and identify areas for improvement for subsequent offerings.

Faculty feedback on using new format

By no surprise, flipping a course requires a significant investment of time, energy, planning, and organization. Even with advance planning and class preparation, and utilizing the strategies described, the first term a new course is offered can by grueling. However, as expected, the authors found that the subsequent offerings of the flipped format required minimal effort and preparation time. A very useful habit was to note what worked (or didn't work) well after each class session, providing a record for the next time the class was offered. This process helped to improve and streamline the course in subsequent offerings. While it was decidedly more difficult to completely revise the geology course than to maintain the existing format, the authors feel the benefits outweighed the investment of time, energy, and resources. Not only did the students enjoy class more (as shown in Tables 2 and 3), teaching the course and interactions with the students were more enjoyable for the faculty as well. This served as a positive feedback loop between the instructors and the students. The format allowed the instructor to work with the students one-on-one, to get to know the students better, to develop an understanding of the student experience and to engage with the students on a deeper level. Previously, the authors had made significant efforts to engage with students more within the lecture-style format, but have found that the revised flipped format provides far more opportunity for student interaction.

Challenges

One of the hardest and time-consuming challenges in flipping the course was the need for appropriate in-class activities for almost every class session. This can be especially difficult if the instructor is relatively new to active learning and does not have a library of materials to draw from. Including an in-class activity for each geology topic meant having at least 24 activities throughout the course, that each filled the majority of the class session time. Further, each activity had to be beneficial to student learning and logistically practical. Although the authors were able to utilize the resources described in Tip 3 for many of these activities, some of the topics required development of completely new materials. The first year of implementing the flipped format quickly revealed which in-class activities fell short of these goals, and the authors took those opportunities to improve the activities in subsequent offerings. In general, the most successful in-class activities were:

1) *Appropriate and relevant for the topic and course*. The main purpose should be to enhance student learning of the geology concept(s). The learning outcomes for the activities are at least as important as the learning outcomes of the recorded lectures and reading materials.
2) *Challenging enough for the students*. Putting an activity together at the last minute can result in class time that feels like "busy work" to the students. This mistake was made by the authors in early iterations of the flipped format.
3) *Encourage interaction and feedback from the instructor.* Achieving the right balance here may require multiple iterations of the activity, as the "right" amount of instructor interaction will also be limited by class size. When activities were too challenging to complete without significant instructor assistance, groups became frustrated waiting for help.

4) *"Worth" something in the course grade.* A grader to grade each in-class activity is certainly helpful, but may not be an option. However, grading activities with even a simple check/check-plus/check-minus scheme when needed helped keep students accountable and engaged during class time (versus not grading the activities at all). The appropriate percentage of the course grade allocated to in-class activities will be specific to the instructor and course, and may require a few iterations.

Although the activity development was challenging, by considering the suggestions above the flipped course now includes a rich assortment of high-quality and effective activities. As was shown in Table 2, 90 % of the students at both universities responded that they agreed the in-class activities (1) improved their understanding of basic geology, (2) improved understanding of the relevance of geology to civil engineering, and (3) provided real-world context for the topics covered.

Conclusions

Faculty at Villanova University and Drexel University collaborated to convert their respective geology courses for civil engineers from a mostly in-class lecture format to a flipped format. The goals of the course overhaul were to improve student engagement, learning, and satisfaction, while minimizing the work load for the faculty in developing new materials and implementing the changes. The authors were able to efficiently and effectively flip their geology courses by utilizing several simple approaches that leveraged free, existing resources. General strategies that worked well in the first attempt to flip the course included: (1) partnering with a colleague, (2) deciding on course layout and logistics upfront, (3) utilizing existing high-quality resources, and (4) using familiar technology. The strategies were described in detail in the paper and examples were provided specifically for the geology course. Suggestions also were provided regarding the challenge of developing effective in-class activities. Positive feedback from both the students and faculty supports the continuation of the flipped format in future years. Administering simple student surveys was a useful, quick tool to gauge students' learning experience and identify areas for improvement for subsequent offerings. A thorough assessment of the impact of the flipped format on student learning and retention was beyond the scope of this paper.

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