Effective Quizzes within an Inverted Classroom Structure

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Abstract:

The inverted classroom structure has received a lot of attention for its ability to utilize technology to move the lecture component out of the classroom allowing more time for active learning opportunities during the in-class meeting times. However, in order for an inverted classroom structure to be effective, students need to complete the required out of class activities, typically recorded lectures. One tool that is commonly used to encourage the students to watch these lectures, and reinforce the concepts covered in those lectures, is quizzes. There are multiple methods for administering these quizzes, including embedding the quiz within the lecture, having online quizzes separate from the lecture, and administering quizzes in class. In addition, the way in which the quizzes are included in the calculation of a final grade can vary significantly. The type, difficulty, and number of questions will also influence the effectiveness of the quizzes.

This paper focuses on the experience gained and lessoned learned through the inversion of a junior/senior level structural design class within the Civil and Environmental Engineering Department at Villanova University. The class has been inverted for three years (four offerings), with each iteration having a different structure for administering the quizzes. Analysis of the various quiz structures is presented through the use of an extensive student survey, as well as the performance of the students on the quizzes. The students' attitude towards the quizzes as well as the entire course was improved though optimizing the format of the quizzes. The most recent iteration of the course resulted in very strong student buy in to the inverted structure, with the vast majority of students coming to class having watched the videos and prepared to engage in the active learning activities that are the focus of the inverted classroom structure.

Introduction

The inverted classroom format is a topic that has received a great deal of attention recently, particularly in the area of engineering higher education. The inverted or "flipped" classroom typically involves moving most or the entire lecture component of the course outside the classroom, allowing more time in class for active learning and group activities that may have traditionally occurred outside the classroom. The lecture component can be delivered in multiple formats, with the most common approach being a video or screen capture of the instructor delivering the lecture. A strong indicator of the interest in the topic can be seen by conducting a search of the 2014 ASEE conference proceedings for the term "inverted classroom" which returns 51 articles. Bishop and Verleger conducted a survey of the research on flipped classrooms in 2013 and found 39 unique blog posts or online articles devoted to the topic.[1]

The reasons for the substantial interest in the inverted classroom format are well founded in the literature. Active learning has been demonstrated to be beneficial for learning for the vast majority of students in engineering classes.[2] However, there is a general perception that with the fixed time available in the classroom and apparently ever increasing demands on that time, it is

difficult to find the time to include significant active learning components. The inverted classroom can be used to increase the classroom time for active learning without reducing the content covered in the course.[3] Also, the inverted classroom allows for learning to occur in a format that more closely resembles how students will be required to learn as practicing engineers, helping to establish a foundation for lifelong learning.[4] Finally, the inverted classroom allows for the flexibility to present information in a variety of formats, better accommodating the diverse learning styles present within the class.[5]

However, the inverted classroom format is not without challenges. Initially, an inverted class requires an increased time commitment by the instructor.[3] In addition, there are potential pitfalls that must be navigated to ensure a positive, effective learning environment. These can include the length and structure of the videos, accessibility of the supplemental (outside of class) content, and motivating the students to take responsibility for their own learning.[6] One method commonly used to encourage students to watch the recorded content is quizzes. In a review of the literature, examples can be found of quizzes integrated into the course in a variety of formats. Talbert[7] gave five minute clicker quizzes at the beginning of class to encourage students to complete the out of class assignment. Bielefeldt[8] did not initially include quizzes as part of her inverted classroom structure, but based upon the data obtained decided to include online quizzes on the recorded lecture content in subsequent offerings.

This paper focuses on the lessons learned regarding effective quizzes through the inversion of a junior/senior level structural design course in the Department of Civil and Environmental Engineering at Villanova University. Quizzes have been incorporated into the course in a variety of formats, and the students' and instructors' perceptions of the effectiveness of the quizzes and the course as a whole will be presented.

Evolution of Structural Design Courses at Villanova University

Prior to 2014, students pursuing Bachelor of Science in Civil Engineering (BSCE) degrees at Villanova University were required to take a three-credit course CEE 3412: Structural Design and a separate one-credit laboratory course CEE 3912: Structural Engineering Lab. These courses were typically taken during the second semester of the junior year and addressed the behavior, analysis, and design of both structural steel and reinforced concrete members. A required course CEE 3401: Structural Analysis was typically taken in the first semester of the junior year and was a prerequisite for both CEE 3412 and CEE 3912. The CEE 3401/3412/3912 seven-credit sequence in structural analysis and design thus defined the required track in structural engineering for all students within Villanova University's broad-based undergraduate curriculum. Similar required course sequences existed in the other disciplinary areas of transportation, geotechnical, water resources, and environmental engineering with a set of primarily junior-level courses that have companion lab courses. Students interested in structural engineering could pursue an additional elective course option in the senior year (CEE 4412: Advanced Structural Engineering) and later elect to enroll in the Structural Engineering Capstone design section.

The course sequence in structural engineering had been offered in this form since 2001. Over the past few years, a number of significant changes have been introduced with this sequence. In

2012, the primary structural design course (CEE 3412) was redeveloped using an inverted classroom format. The course was offered in this format for two years, with some minor changes introduced in the second year. In 2014, CEE 3412 and CEE 3912 were eliminated and replaced with two new courses that separate the content associated with steel and concrete. The two new courses are CEE 3402: Structural Steel Design and CEE 4404: Reinforced Concrete Design. Both courses utilize an inverted classroom format and include an integrated laboratory component. All BSCE students must take at least one of the two courses as a degree requirement, while students with an interest in structural engineering may choose the second course as an elective. This change eliminated the previously offered senior elective (CEE 4412), which primarily addressed modern structural analysis techniques which are also covered in an introductory graduate level course that qualified students may still take. The change also reduced the required track in structural engineering by one credit hour (from seven to six).

The evolution of the junior structural design course that is the focus of this paper is summarized in Table 1. Specific details regarding course structure such as enrollment, number of sections, and class meeting times are given to provide context for the discussions on specific components of the inverted classroom format that follow.

Table 1 – Evolution of Structural Design Course Format(s) at Villanova University

Semester	≤ Spr. 2011	Spring 2012	Spring 2013	Spring 2014	Fall 2014
Course Number	CEE 3412	CEE 3412	CEE 3412	CEE 3402	CEE 4404
Course Title	Structural Design	Structural Design	Structural Design	Structural Steel Design	Reinforced Concrete Design
Credit Hours	3	3	3	3	3
Instructor	Professor A	Professor A	Professor A	Professor A	Professor B
Lab Integrated Into Course?	No [a]	No [a]	No [a]	Yes	Yes
Required/Elective	Required	Required	Required	Required [b]	Elective [b]
Typical Student Rank	2nd Semester JR	2nd Semester JR	2nd Semester JR	2nd Semester JR	1st Semester SR
Class Meetings (per week) [c]	3 x 50 minutes	3 x 50 minutes	3 x 50 minutes	2 x 75 minutes	2 x 75 minutes
Format	Classic	Inverted	Inverted	Inverted	Inverted
Student Had an Inverted Course in CEE Prior to This?	No	No	No	No	Yes
Total Enrollment [d]	59 [e]	47	46	47	31
# of Sections	2	2	2	2	1

[a] CEE 3912 – Structural Engineering Laboratory offered as a separate required co-requisite 1-credit required course that meets for one 180-minute period every other week
[b] Students must take either CEE 3402 or CEE 4404 to graduate, but typically would only take CEE 4404 without also taking CEE 3402 if they are off sequence
[c] Academic semester is 14 weeks long
[d] Total enrollment of all sections
[e] Three-year average (2009 to 2011)

Transition to the Inverted Classroom Format

The decision to shift from a more classical course structure to an inverted classroom format in the Structural Design course discussed in this paper was motivated by a number of factors. Foremost was the recognition that it makes little sense to focus most of the precious class time, where faculty and students are able to interact, on the lowest two levels of Bloom's taxonomy (knowledge and comprehension), while using primarily problems related to the third level of the taxonomy (application) for evaluation of student performance on exams. The inverted course format, particularly with a requirement for students to watch theory-based lectures prior to coming to class where they work on application problems, addresses all three lower levels of Bloom's taxonomy in a comprehensive, logical manner. Students prepare for the application level by initially addressing the lower two levels on their own, and then the instructor can structure problem-based learning in the classroom to focus on all three levels by embedding and reinforcing theoretical points within the development of the problem solutions.

The inverted format discussed herein utilizes several components as part of the overall course structure. The primary components include the lectures recorded for out of class viewing, the quizzes associated with these lectures, and the problem sets that are solved either in class or for homework. Additional components include integrated laboratory periods and calculation-based semester-long projects. In-class exams form the primary assessment mechanism for evaluating learning and establishing student grades.

The increased focus on problem solving in an inverted format led to significant changes in the way that time is spent during class meetings. Prior to inversion about half of the total class meeting time was spent on lecture content, and only about a quarter of the total class time was spent on problems. The problems that were included were presented with the instructor completely leading the solution. In many cases, complete or partial solutions were given in the notes to facilitate a fast-track completion of the problem before the class meeting period ended. After inversion, the amount of time spent on lecture content during class meetings was drastically reduced to less than 10 percent. As a result, approximately two-thirds of the in-class time was able to be spent on problem solving. Not only are more problems solved than in the pre-inversion course, but the problems are solved in real-time and with more discussion of the concepts demonstrated by the problems.

Lecture Videos

Recorded lecture videos are a critical component of the inverted course structure since students are required to watch these theory-based lectures online before coming to class to work on problems that apply this theory. These videos are posted on a course learning platform such as BlackBoard or Mediasite for student viewing. While students are required to view the lectures before class, they are also able to go back and review the lectures as needed for further understanding once they have been introduced to how to apply the theory.

For the first inverted course in Spring 2012, lectures were recorded using the College of Engineering's distance education facilities, which resulted in lectures that include both video of

the instructor presenting the lecture and the presentation. The same recorded lectures were used for the second offering of the course in Spring 2013. When the decision was made to split the course into separate steel and concrete courses, it became appropriate to re-record the videos for several reasons. First, this allowed the videos to be consistent with the new course structure including course names, numbers, and more importantly calendars and syllabi. Secondly, feedback from the first two offerings indicated that it was desirable to break lectures into smaller segments rather than the large single segments that were initially used. Finally, this allowed for consistency between in-class and out-of-class style and terminology since the faculty member (Professor B) teaching the new concrete course was not previously involved with the content in the original course.

While many specific lecture slides could be reused because the content had not changed, all lectures were re-recorded before the first offering of either CEE 3402 or CEE 4404. New recordings were made using Camtasia screen-capture recording software, therefore there was no need for the use of college staff or facilities. Furthermore, the use of Camtasia greatly expanded the ability to edit lectures after the initial recording was made. The videos produced using Camtasia included only voice and screen capture, and the instructor does not appear in the videos. No negative comments have been received from students regarding the lack of video to complement the audio recording of the instructor.

Table 2 – Statistics on video lectures and lecture-based quizzes for each inverted class offering

	Spring 2012	Spring 2013	Spring 2014	Fall 2014
	CEE 3412	CEE 3412	CEE 3402	CEE 4404
	Structural Design	Structural Design	Structural Steel Design	Reinforced Concrete Design
	Professor A	Professor A	Professor A	Professor B
Number of recorded lectures	31		38	22
Median recorded lecture length	38:49		8:57	12:21
Total number of quiz questions	100	100	100	43
Quiz implementation	at beginning of class	at beginning of class	online, before class	online, before class
# of times quiz may be taken	once	once	unlimited	unlimited
Grading mechanism	manual	manual	automatic	automatic
Percentage of course grade allocated to lecture-based quizzes	16 %	0 to 10% [a]	4.4%	5%
Average composite quiz grade	71.2%	63.9%	96.9%	96.5%

[a] Composite quiz grade could be used to replace an exam grade. Each exam worth 10%.

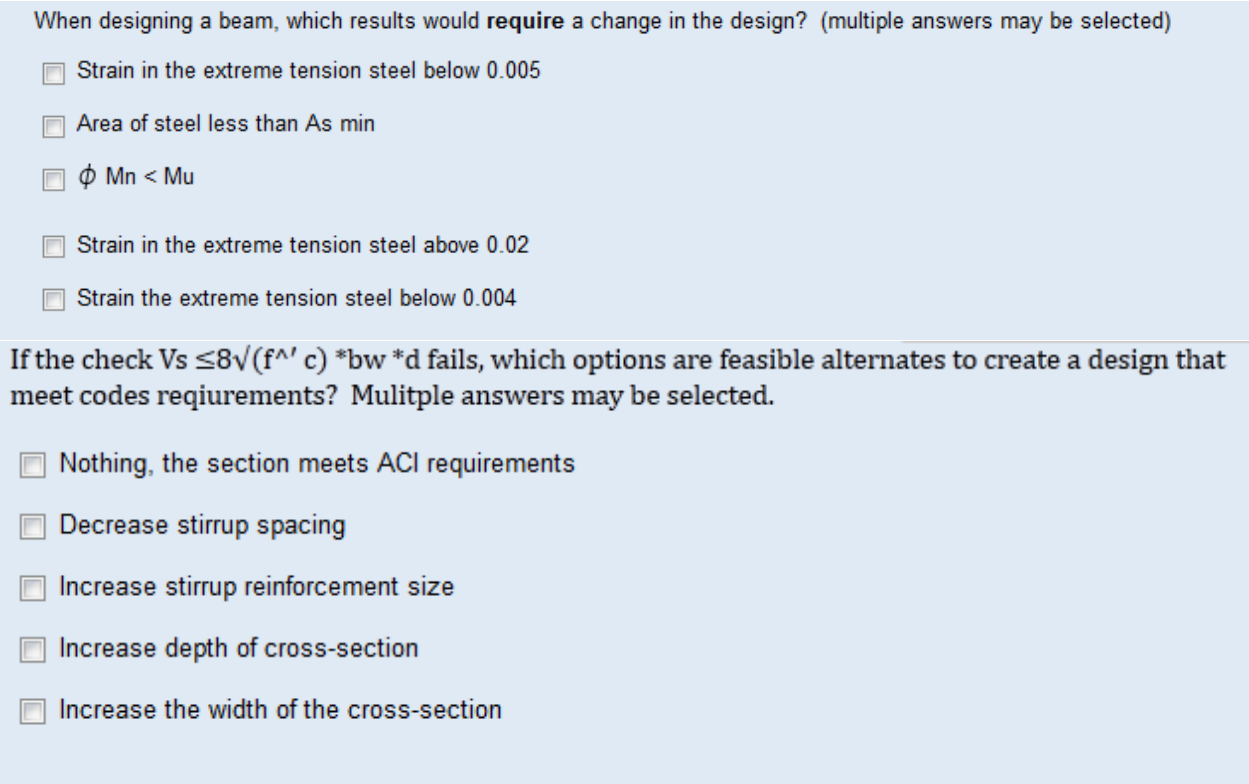
Statistics related to the recorded lectures used in each inverted course are shown in Table 2. Note the dramatic difference in lecture lengths between the initial inverted offerings of the combined steel and concrete course as compared to the more recent 2014 offerings of the separate courses. Despite the course content remaining essentially the same, the total lecture time has been cut in half and distributed over two courses. This was the result of a concerted effort on the part of both instructors to keep the new recorded lectures short and very focused. Points are not repeated multiple times in the lectures because the important lecture content will

be emphasized within the problems solved in class. Extra comments and stories that deviate significantly from the core content are not included, or are edited out before publishing the lecture video. The recognized goal is to prepare students by providing them the necessary background theory and a few key takeaways before getting into the problem solving sessions in the class meetings. Data from student surveys indicates that the shortening of lectures has had a tremendous benefit on the perceived time burden associated with the inverted class structure. There is no question that this improvement has had a great positive impact on the success of the inverted format in the new courses.

Quizzes

Lecture-based quizzes are a critical component that complements the recorded lecture videos. Quizzes were constructed using one to five multiple choice questions that emphasize theoretical concepts and do not require extensive calculations. Sample quiz questions from the Fall 2014 offering of CEE 4404 may be seen in Figure 1. Important statistics related to these lecture-based quizzes are provided in Table 2.

Figure 1 – Sample Quiz Questions from CEE 4404



Before the methods in which quizzes have been implemented in each course offering are presented and discussed, it is noted that feedback on the effectiveness of the quizzes and other components of the inverted course structure has been gathered through the use of a comprehensive student survey administered at the end of each semester. These surveys were administered by handing out the survey during the last week of class and requiring students to

submit it before the final exam, which ensures a near 100% return rate. The surveys were anonymous and included approximately fifty multiple choice rating questions and an opportunity for open student comments at the end of the survey on anything related to the inverted format of the course. Surveys used a simple 1 to 5 scale for responses:

1 = Strongly disagree
2 = Mildly disagree
3 = Neutral
4 = Mildly agree
5 = Strongly agree

Student survey responses related to lecture-based quizzes are shown in Table 3.

Table 3 – Student responses on survey questions related to lecture-based quizzes

	Spring 2012	Spring 2013	Spring 2014	Fall 2014
	CEE 3412	CEE 3412	CEE 3402	CEE 4404
	Structural Design	Structural Design	Structural Steel Design	Reinforced Concrete Design
	Professor A	Professor A	Professor A	Professor B
Quizzes encouraged me to watch the lecture and learn the material in the lecture.	3.9	3.5	4.2	4.4
The questions asked on concept quizzes were focused on appropriate material and concepts.	3.3	4.2	4.9	4.5
The quizzes count as an appropriate part of my overall course grade.	2.3	3.4	4.2	4.2
Quizzes were fair.	2.9	4.0	4.9	4.2
The quizzes count as an appropriate part of my overall course grade.	2.3	3.4	4.2	4.2
My quiz grades reflect my general understanding of what I get out of watching the lecture videos.	2.5	2.2	3.4	3.7

The manner in which lecture quizzes have been implemented, and the defined purposes for which they are used, have evolved over the different inverted class offerings since 2012. In the original inverted course in Spring 2012 and then in the following Spring 2013 offering, quizzes were given at the beginning of the class meeting that followed the lecture viewing period. Quizzes could only be taken once, they were given on paper, and the instructor had to grade them manually. As demonstrated by both the grade performance shown in Table 2 and the student responses shown in Table 3, students did not like this format. Students felt that the quizzes were too “tricky” because it was too difficult to remember the critical information from a long lecture viewed the day or night before the quiz. The instructor would often observe students stressfully and hurriedly studying before the beginning of the class period, and students

who watched the videos were frustrated by low quiz grades, particularly since the quizzes counted as 16% of the final course grade.

In order to improve the vibe within the course, the quizzes were recast in 2013 as something that could only be helpful to the students' final course grades. Students were able to use their composite quiz grade to replace their lowest exam grade, so the quizzes would count anywhere from zero to ten percent of the grade. Unfortunately, this did not have the desired effect on changing students' attitudes towards the quizzes. Many students simply abandoned the idea of watching the lectures and studying for the quizzes, and simply guessed. This was especially apparent later in the semester. Many of these students were those who were doing well on the exams and simply didn't need the quizzes to help their course grade. The composite quiz average dropped all the way to 63.9 percent, as shown in Table 2. Note that at the same time, students were less interested in watching and learning from the recorded videos, as indicated by the responses in Table 3.

In the newer separate steel and concrete course offerings, the quizzes have been implemented in a completely different manner. Quizzes have been moved online and may be taken by the student immediately after they watch the lecture. Furthermore, the student is able to see his or her grade immediately and may retake the quiz as many times as desired until all questions have been answered correctly. The instructors also emphasize the role of the quizzes as a formative assessment tool, and encourage the student to learn from the quizzes, as the questions asked relate to the most important concepts from the lecture. This approach has made the quizzes a far more valuable course tool and students are far more receptive to this quizzing approach. The weight of the quiz grade has also been reduced to about 5 percent of the course grade, which has reduced the stress level that some students have with regard to the quizzes, while still providing enough motivation to encourage the students to watch the lectures.

In CEE 3402 (Spring 2014), the instructor also allocated just over 2 percent of the course grade as credit for watching the lecture videos. Although the authors don't feel that this is absolutely necessary, this was done as a means to discourage a student from simply logging on and guessing at quiz responses without watching the lectures. Based on student survey responses and other informal feedback, students report that they are indeed watching the lecture videos. The instructor did not actually check on the students for this small portion of the course grade because it was not perceived to be worth the time investment required to track this data. However, as technology improves it is becoming much easier to obtain data on whether students actually watch the videos, when they watch the videos, and whether they watch the entire video. If this data can be gathered easily, then it may be evaluated in future course offerings rather than considering these as free motivational points toward the final course grade.

Overall Impacts

Table 4 summarizes student responses on general questions related to the use of the inverted class format. The responses clearly indicate an increasing acceptance of the inverted format by the students in each successive offering. These findings are consistent with the instructors' feelings that the course improved significantly as the inverted format in general, and quiz structure in particular, was refined between the first and second offerings, and then even more as

the original course was split into separate steel and concrete courses with integrated labs. It is also important to note that with the separate steel and concrete offerings in Spring 2014 and Fall 2014, respectively, the inverted format has been well accepted by students in courses offered by two different instructors.

Table 4 – Student responses on survey questions related to the use of the inverted class format

	Spring 2012	Spring 2013	Spring 2014	Fall 2014
	CEE 3412	CEE 3412	CEE 3402	CEE 4404
	Structural Design	Structural Design	Structural Steel Design	Reinforced Concrete Design
	Professor A	Professor A	Professor A	Professor B
I have met the individual course objectives for this course. [a]	4.3 (4.1 – 4.6)	4.6 (4.4 – 4.8)	4.7 (4.6 – 4.9)	4.6 (4.3 – 4.8)
I feel that the format of this course improved my overall learning over a classical in-class lecture format.	3.7	4.3	4.4	4.6
I feel that the format of this course improved my conceptual understanding of structural behavior over a classical in-class lecture format.	3.5	3.7	3.8	4.1
I feel that the format of this course improved my ability to apply knowledge in solving basic structural design problems over a classical in-class lecture format.	4.0	4.3	4.2	4.5
I would prefer all of my similar (standard CEE, math, science lecture/problem solving-type) courses use the format that this course did.	2.5	3.3	3.5	4.2
In hindsight and specifically for this course, I prefer the format of this course over a traditional in-class lecture format.	3.3	4.2	4.4	4.6
I feel that the format of this course required a more substantial investment of my time over a classical in-class lecture format.	4.5	4.1	2.4	3.3

[a] Since specific course objectives vary by course, this response is presented as an average response for all objectives in that course. Actual survey data is broken down by individual course objective. The range of mean responses for individual outcomes is shown in parentheses.

Overall, students feel that the inverted format improves their overall learning and ability to apply knowledge, which makes sense given the problem-centric nature of the inverted courses. To a lesser extent, but just as important, students feel that the inverted format improves their conceptual understanding. The formative assessment provided by the conceptual quizzes likely contributed to this improved understanding. Students indicate a clear preference for this format in these structural design courses, and their interest in having the inverted format implemented in other technical courses is growing with each successive offering.

A clear trend that is also important to note is that students in the 2014 offerings of steel and concrete did not feel that the inverted format required a more substantial investment of time on their part. Students in the 2012 and 2013 offerings before the split did, however, perceive a substantially larger time commitment. There is no question that the content was overwhelming in the original CEE 3402 course since steel and concrete were both being covered in the same course. The course simply had too much material and that was the primary motivation for the departmental decision to restructure the course sequence. Furthermore, differences in the length and number of recorded videos, and in how quizzes on video content were implemented within the course probably contributed to this perception. It is logical to conclude that there is a correlation between the students' perceived time commitment and their acceptance of the inverted class format.

Conclusions

This paper examines lessons learned through inverting an upper level undergraduate course in structural design. Based on the results of an extensive student survey, instructor experiences, and the assessment of student performance the following conclusions can be drawn:

- Quizzes can be an effective method for motivating the students to watch the videos and can also be used as a form of formative assessment when implemented in an appropriate manner
- Quizzes implemented in a way that emphasizes understanding of the material and allows students to learn from their mistakes can improve both student's perception of the inverted classroom format and their perceived conceptual understanding
- Short, focused recorded lectures improve student acceptance of the inverted classroom format, resulting in an increased motivation to watch the videos and increased perception of the value of the videos to improve their theoretical understanding
- Students feel that the inverted classroom format improves their conceptual understanding of the material as well as their ability to apply that knowledge through problem solving over a more traditional classroom format

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