Inverting the Lecture Paradigm for a Multidisciplinary Course

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Session: Tools, techniques, and best practices of engineering education for the digital generation

Abstract

The traditional lecture course is based on a simple premise; that students will be actively involved in their learning. These active learners read textbooks and seek out supplemental sources of knowledge. They try to understand concepts rather than just memorize terminology. They attempt problems beyond those assigned for homework. Certainly these active learners still exist, particularly in upper level college courses, but in first and second year courses, the passive learner is the more common species. These passive students expect that all relevant information is given to them in lecture and believe that if they can solve problems exactly like those assigned for homework, they are knowledgeable. In addition, the diversions available today present a unique challenge to those of us teaching the millennial generation. While instructors have always been challenged to hold the attention of their students during lecture courses, they now must compete with text messaging and wireless internet access. Instructors may wonder if anyone at all is listening to the lecture. A move away from traditional lectures has been afoot at colleges and universities across the country, from courses taught entirely from a guided inquiry perspective, to classes that disperse problem solving time within lecture periods and those that have moved lecture outside of the classroom entirely. Here we report on our experience with the latter in an interdisciplinary, sophomore level course; Materials in Engineering Systems. Lectures were prerecorded using the Tegrity system and made available to students via Blackboard for viewing prior to class. Class meetings then focused solely on problem solving. This inverted instructional approach, as assessed by student performance on the final examination and course evaluations, shows that students improved their abilities to perform calculations, but not their understanding of conceptual material.

Introduction

A traditional college instructional approach is for course content to be delivered to students via lecture and for students to take time on their own to read, think and practice calculations until they have learned the material. Some universities, particularly those with a supply of graduate teaching assistants often have recitation sections for students to ask questions, discuss course content and further practice problem solving. Instructors at colleges and universities without recitation sections often try to squeeze problem solving time intermittently within the scheduled lecture, hopefully without sacrificing the quantity or depth of content covered in the course.

This traditional approach also presumes that students will be active learners; reading textbooks, asking questions in class and doing homework problems beyond those assigned. Many students, however, are passive learners, expecting that they will learn by attendance alone. As lecture instruction is inherently passive approach to teaching students, many college
instructors have re-envisioned their courses to encourage (and in some cases require) more active participation of students. These approaches range from the use of student response systems during lecture, to the elimination of lecture entirely in favor of guided inquiry learning. [1]

In parallel to the changing attitudes of college instructors to lecture instruction has been the development of technological resources for academic use. Course management systems such as Blackboard have allowed instructors to post grades and homework keys, give online quizzes, and link students to valuable internet content. In addition, web-based video services, Tegrity Campus [2] allow instructors to record lectures in the classroom, their office or even at home. Recorded video content has been used in a number of different ways to supplement and/or replace the classroom lecture. [3-7] In some cases, online videos provide a means of ensuring consistency among a large number of course sections. [4] Brecht and Ogilby showed that the availability of extra course related content prepared by the course instructor and closely linked to topics covered in class improved the grade distribution of the students. [5] Other studies [6,7,8] have shown that students who viewed online lectures performed as well as students who received an identical lecture in the classroom.

The use of prerecorded video content that is viewed by students before they come to class has the potential to open up more classroom time for student-student and student instructor interaction without sacrificing the quantity or depth of course content delivered. This paper presents the experience and results of teaching a sophomore level engineering course with this “inverted” approach and assesses the impact of such approach on students understanding to technical concepts and their ability to perform calculations.

The Course

Materials in Engineering Systems (EAS 213) is a sophomore level course that is part of the University of New Haven’s Multidisciplinary Engineering Foundation Spiral Curriculum. This curriculum was developed to prepare chemical, civil, mechanical and electrical engineering students for the challenges and trends discussed in “The Engineer of 2020” from the National Academy of Engineering. [9,10] This course attempts to address one of the major trends identified, “the growing complexity, uncertainty, and interdisciplinary foundations of engineered systems” by providing a broader perspective on materials to engineering students. This means broadly interpreting “materials” to include the common gases and liquids used in engineering. The first half of the course focuses on the physical properties of fluids and the second half on the physical and mechanical properties of solids. A review of the curriculum and the course role is available online as an ASEE Conference publication [9].

These topics are combined through a focus on properties and selection while still retaining a somewhat traditional approach for solid materials as in material science classes. Processing details for ferrous and nonferrous alloys are not included, while the metal alloy phase diagrams and heat treatments are still included, but with less emphasis. The temperature dependence of ferrous and nonferrous engineering alloys is paralleled with the temperature dependent behavior of gases and liquids, allowing for a more general view of all materials, and providing early emphasis on the deviation from ideal behavior for engineering gases, liquids and solids. While this course may seem an unusual mix of topics it is not unique; the course is based in part on the pioneering efforts of faculty at Texas A&M as part of the NSF Foundation Coalition. A course with very similar scope “Properties of Matter” [11] was introduced as a science-based development of properties of solids, liquids, and gases.
Methodology

EAS 213 meets twice weekly for 100-minute sessions, enrolling approximately 24 students per section. Since the course’s inception in 2005, it has been taught primarily in a traditional format; in class lectures were given by the instructor and were often followed by in-class problem solving time. While three different instructors have taught sections of EAS 213, this paper only compares the instructional methods used by one instructor in the falls of 2008 and 2009. The instructor followed the typical format in the fall of 2008. In the fall of 2009, students watched pre-recorded lectures prior to coming to class. As such, the instructor was able to devote most of the in class time to problem solving. The effectiveness of this inverted approach is assessed through student performance on the final examination as well as student self-assessment on course evaluations. All statistical comparisons were performed with the SPSS software.

Lectures were recorded using the Tegrity Campus system to be downloaded or played online by the students in the course. The lectures were annotated (using a digital pen) voice over PowerPoint presentations that were between 30 and 90 minutes in length, depending on the topic. Eleven lecture recordings were made and students were required to view them prior to attending class. In addition, the regularly scheduled classroom meetings, which were focused primarily on problem solving, were also recorded and made available for student viewing outside of class with the hope that students would use these recordings to review problem solutions. These recordings consisted of calculations done using Excel spreadsheets and solutions to problems written with a digital pen, both accompanied with sound commentary. For the Fall 2009 section of this course, a total of forty recording were made for the semester.

When the students viewed the lecture online or viewed at home after a brief download and installation step, the interface provided a list of courses, recording dates and total recorded time so the students could allocate appropriate time for viewing the lectures at home. Once an individual lecture was selected, a chapter selection window allowed the students to see thumbnail images of all the PowerPoint slides in a lecture, allowing students to start at the beginning or view a single slide in the middle of the lecture presentation. When a chapter is selected for viewing, a playback window opens the presentation.

During the first week of the semester, students viewed the Tegrity recordings of the lecture prior to coming to class and in the online mode. Because some students had difficulty viewing the presentation online due to slow internet connections, Tegrity settings were changed to allow the students to download the recordings prior to viewing them. This makes it difficult to assess the student viewing time, as data on viewing time and frequency of Tegrity recordings requires that they are viewed in an online mode.

Comparison of Student Groups

This study involves the comparison of two sections of EAS 213 taught by the same instructor in Fall 2008 and Fall 2009. A comparison of the student populations from Fall 2008 and Fall 2009 was done to determine if there were any significant differences between the two groups. Table 1 gives the average cumulative grade point averages (GPA) and standard deviations of students in both sections at the time they were taking the course. (In other words, the cumulative GPA of their first three semesters at the University of New Haven.) A statistical comparison of the two populations shows that the difference between the means is not significant at a confidence interval of 95% (p = 0.194). This means it is reasonable to compare the instructional methods used with these two groups of students.
Table 1: Comparison of Grade Point Averages of students enrolled in the Fall 2008 and Fall 2009 sections of EAS 213.

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
<th>Standard Error of the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2008</td>
<td>3.01</td>
<td>0.50</td>
<td>0.11</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>3.23</td>
<td>0.51</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Final Examination

The final examinations given for EAS 213 were composed of two parts. Part 1 of the final exam was the conceptual section where students were asked a series of multiple choice questions on topics throughout the course. Part 2 was the calculation section, which contained a number of problems ranging. The final exams given in Fall 2008 and Fall 2009 are not identical, but had the same format and contained many of the same questions.

A sample of the conceptual questions asked in the final exam is provided in Table 2. The average student grade for the conceptual students was 57.0% (standard deviation for Fall 2008 and 57.6% for Fall 2009 and is summarize in Table 3. A comparison of these results using a t-test gives a p-value equal to 0.917, which indicates that the difference in the mean grades is not significant at a level of 95% confidence.

A sample of the calculation questions from the final exam is given in Table 4. The average grade of the students in Fall 2008 is 56.4% and the average grade of students in Fall 2009 is 79.8%. A summary of these grades is given in Table 3. A t-test comparing the means (p =0.000) confirms that the difference between the student performance between Fall 2008 and Fall 2009 is statistically significant. A histogram of student performance on the calculation section is presented in Figure 1. It is clear that, compared to the Fall 2008 sections, few students in the Fall 2009 class earned less than 50 percentage points and nearly 50% of the class obtained over 90 percentage points on the calculation section of the final exam.

Table 2: A sample of conceptual questions given on the EAS213 final exam in Fall 2008 and Fall 2009. These questions appeared on the Final Exam both years.

1. What is the fundamental assumption for computing partial pressures of a gas in a mixture (without compressibility or non-ideal gas behavior?)
   a. Each gas independently fills the volume.
   b. Each gas is at the full pressure of the mixture.
   c. Each component gas is at a partial temperature of the full temperature of the mixture.
   d. The equivalent molar weight of the mixture is the density weighted sum of the components.

2. The thermal diffusivity is the conductivity k divided by the heat capacity (density *Cp). If the material A has a very low thermal diffusivity and material B a very high one, heat applied to one side of both A & B will cause:
   a. The heat to spread more rapidly through A than B
   b. Material B to absorb more heat than material A.
   c. Material A and B will behave the same way.
   d. Material B will transfer the heat more quickly than material B.

3. A rod of material A has a larger Young’s modulus than a rod of material B with the same dimensions. If the two rods are both loaded with the same force.
a. A will stretch more than B.
b. B will stretch more than A.
c. A & B will stretch the same amount.
d. Can’t tell from the information given.

Table 3: Comparison of student performance on the Final Exam in Fall 2008 and Fall 2009. Average grades on conceptual and calculation questions is compared.

<table>
<thead>
<tr>
<th></th>
<th>Average Grade</th>
<th>Standard Deviation</th>
<th>Standard Error of the Mean</th>
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<tbody>
<tr>
<td><strong>Conceptual Questions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2008</td>
<td>57.0%</td>
<td>22.3%</td>
<td>4.98</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>57.6%</td>
<td>11.8%</td>
<td>2.78</td>
</tr>
<tr>
<td><strong>Calculation Questions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall 2008</td>
<td>56.4%</td>
<td>19.4%</td>
<td>4.33</td>
</tr>
<tr>
<td>Fall 2009</td>
<td>79.8%</td>
<td>17.7%</td>
<td>4.17</td>
</tr>
</tbody>
</table>

Table 4: A sample of calculation questions given on the EAS213 final exam in Fall 2008 and Fall 2009. Table 1: A sample of conceptual questions given on the EAS213 final exam in Fall 2008 and Fall 2009. These questions appeared on the Final Exam both years. These questions appeared on the Final Exam both years.

1. You are pushing horizontally on a large rectangular box (100 kg) that has the dimensions of 1 meter on each side, with a force of 100 Newtons. The bottom of the box is sliding on a thin layer (0.1 mm) of glycerin and the temperature is 0 °C. How fast is the box sliding along the flat ground?
   a. 0.1 m/s
   b. 0.01 m/s
   c. 0.001 m/s
   d. 0.0001 m/s

2. Iron has a crystal structure of BCC at room temperature and a density of 7.87 g/cm³. At 1000 °C the crystal structure changes to FCC (γ-iron). Calculate the new density given that iron in either phase still has a molar mass of 55.85 g/mol and atomic radius = 0.124 nm. (Hint: calculate the lattice parameter first.)
   a. 6.6 g/cm³
   b. 7.6 g/cm³
   c. 8.6 g/cm³
   d. 9.6 g/cm³

3. You would like to produce a 1 cm thick sheet of unalloyed oxygen-free copper that has yield strength of approximately 40,000 psi. What is the required initial thickness of the sheet?
   a. 0.5 cm
   b. 1.5 cm
   c. 2.0 cm
   d. 2.5 cm
The year to year similarity in student performance on the conceptual questions suggests that the students are able to learn this material to the same extent, regardless of the course format. On the other hand, the inverted format did significantly impact the ability of the students to perform calculations. This makes sense given that the students spent 200 minutes a week working on the mechanics of problem solving with the assistance of the course instructor.

In addition, when the analysis was repeated, comparing students according to their GPA (top half vs. bottom half of each class), the results were similar. Both high and low GPA students performed at the same level on conceptual questions in Fall 2008 and Fall 2009, with no significant difference and both groups showed an improvement in their calculation grade, with no significant difference between the two.

**Reading and Note-Taking Assessment in Fall 2009**

Midway through the Fall 2009 semester, it was clear from midterm exams administered in the course, that student performance on conceptual questions was, while perhaps not any worse than the previous year, certainly not any better. A series of brief quizzes were implemented to test conceptual understanding and note taking from reading assignments and the Tegrity lectures. Five quizzes were given after the midpoint in the fall 2009 semester, with each including a number of brief concept/note taking questions and one or two very short computational problems. Each quiz was closed book and open notes, limited to 10-20 minutes and automatically graded on blackboard. Average scores for the quizzes are shown in Figure 2.

After the dismal performance of 40% of the chapter 6 quiz, the instructor gave an anonymous study skills survey where students ranked two statements using the Likert scale (1=Strongly Disagree through 5 = Strongly Agree.). The average ranking of statement; “I took good notes from the textbook and had them available during the quiz” was a 2.5 (standard deviation = 1.32) and their ranking of the statement; “I took good notes from the Tegrity lecture and had them available during the quiz” was a 2.7 (standard deviation = 1.39) In other words, more than 50% of the students were not doing a good job taking notes from either their textbook or the prerecorded lectures. As note taking is integral to the student learning process, student understanding of conceptual material may not improve until note taking skills are improved and regularly used. It should be noted that after students took the study skills survey and revealed their study habits, their performance on these quizzes improved for the rest of the semester.
End of Semester Evaluations

End of semester course evaluations were distributed to students in both sections of EAS 213. Students rated the course, the instructor and their ability to meet course outcomes through a survey as well as through free response questions. Summary of student responses to these survey questions is given in Table 6.

According to the survey, students found the lectures in 2009 more “informative and interesting than in 2008 (p = 0.03). While it is unclear if the Fall 2009 students were commenting on the prerecorded lectures or the classroom time, it is likely that the are commenting on the latter and, not surprisingly, they found the in-class time more interesting and informative. While their peers during the Fall of 2008 were spending at least half of all class time listening to the lecture, they were actively solving problems. However, this enthusiasm did not translate to an overall increase in work by these students. As a whole, students spent about the same amount of time outside of class on the course per week (p=0.784). Since students in the Fall of 2009 would need to spend part of this time on viewing the pre-re recorded lectures, presumably they would be spending less time on the other out of class assignments, such as reading and homework. Their ability to apply analytical methods, on the whole, was not impacted because they were spending 200 minutes per week on applying these methods under the guidance of the course instructor. This explains their better performance on the calculation section of the final exam as compared to Fall 2008 students.

<table>
<thead>
<tr>
<th>Table 6: Results of Student Evaluations in Fall 2008 and Fall 2009.</th>
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<tbody>
<tr>
<td>1. Lectures were informative and interesting.</td>
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<tr>
<td></td>
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<tr>
<td>Average Response</td>
</tr>
<tr>
<td>(Scale of 1-5)</td>
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<tr>
<td>Fall 2008</td>
</tr>
<tr>
<td>Fall 2009</td>
</tr>
<tr>
<td>2. How many hours per week (outside of class) did you spend?</td>
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<tr>
<td>Average Number of Hours</td>
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<tr>
<td>Fall 2008</td>
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<td>Fall 2009</td>
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Conclusion

The use of video content as a supplement or replacement of classroom lectures has been proposed as a number of advantages for students. They can review lectures as a whole and at their own pace, pausing as necessary to work through problems, read their text or just take a break. In addition, it may improve the learning of students that struggle with learning through textbooks or the pace of lecture delivery by an instructor. Furthermore, students generally have a positive view of obtaining some level of instruction through video content.

Here we have shown an additional advantage; students’ ability to perform the mechanics of problem solving is improved significantly through an inverted approach to instruction. Furthermore, the students’ understanding of course concepts was not sacrificed with this approach. That does not mean, however, that additional effort and better strategies should not be put into improving student learning of course concepts. One approach would be administering regular, graded quizzes on reading and viewing assignments that encourage students to improve their note taking skills.

References:

2. Tegrity Campus 2.0, www.tegrity.com

Biographies

Nancy Ortins Savage, Assistant Professor of Chemistry at the University of New Haven, received her B.S. in Chemistry from Rensselaer Polytechnic Institute and her Ph.D. in Analytical Chemistry at The Ohio State University. Her research is on the development of new materials for application as gas sensors.
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