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Variations on Flipping a First-Year Engineering Computing Course

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Variations on Flipping a First-Year Engineering Computing Course

Abstract

At the University of Cincinnati, three common courses were introduced during the 2012-2013 school year to provide first-year students with hands-on experiences in engineering and a link between engineering and the required mathematics and science courses. Two of these courses, Engineering Models I and II, form a two-semester sequence of interdisciplinary courses in which students apply fundamental theory from algebra, trigonometry, calculus and physics to relevant engineering applications chosen from a variety of disciplines. MATLAB® is introduced and progressively developed as a programming tool to enable students to explore engineering concepts, to investigate solutions to problems too complex for hand solutions, to analyze and present data effectively, and to develop an appreciation of the power and limitations of computer tools. Students are introduced to such ideas as interpolation, curve-fitting, and numeric differentiation and integration, through applications areas such as data analysis, image processing, communications, position tracking, basic mechanics, and system modeling.

The Engineering Models sequence was required for all incoming first-year engineering and engineering technology students starting with the 2012-2013 academic year. Lectures, recitation activities, homework assignments, exams, and projects were common across all sections, though some variation existed in how lectures were delivered. As a result of this variation and comments provided by students on end-of-semester surveys, a flipped pedagogy was implemented for the 2013-2014 academic year in these courses. For the Engineering Models I and II courses, videos were created from the lecture material covered in the first offering. Students were required to watch these videos prior to lecture and take a short quiz at the start of each lecture. Lecture time was devoted to solving problems, either in small groups or as a class.

Feedback from students led to the development of several modifications to the courses this year. The paper describes the changes to the courses and uses student performance data and the end-of-semester student surveys to analyze the effectiveness of the various modifications made for the 2014-2015 academic year offering of the course.

Introduction

In a flipped pedagogy, traditional lecture content is assigned as homework, freeing the instructor to use the designated lecture time to focus on solving problems and addressing common misconceptions.[1] Flipped classrooms have been implemented in a variety of math, computing and engineering courses. A comprehensive survey of the research on flipped classrooms is provided by Bishop and Verleger[2] who found that students tend to prefer in-person lectures rather than videos but prefer the active learning opportunities that the flipped classroom affords. Many of the early research studies focus only on student attitudes and perceptions toward the inverted classroom pedagogy.[3-6] For example, J. Foertsch et al used the flipped classroom approach in a computer course for sophomores and juniors called Engineering Problem Solving using Computers.[3] Survey data from their study indicated that students in the flipped version of the course gave significantly higher ratings to all aspects of the course; however no mention was made of the effect on student learning. Some of the recent research studies focus on whether or not the flipped classroom has an effect on student learning and performance.[7-9] At Harvey Mudd, a controlled study was performed in selected engineering, science, and math courses.[7] One section of the course was taught using the traditional lecture approach while another section was taught by flipping the classroom. There was no significant difference in performance between students in the traditional sections and students in the flipped classrooms. At Ohio State, the flipped classroom was implemented in a first-year engineering MATLAB course.[8] A comparison of students' final exam scores to the final exam scores from the previous year showed no significant change in performance. However, there was a strong correlation between students' performance on pre-lecture activities and grades on in-class assignments. In a three year study, Redekopp and Ragusa analyzed the performance and perceptions of students enrolled in a computer architecture course that had been flipped.[9] They found that student performance on the final exam and basic assignments, which they consider to be lower order learning outcomes (remember, understand, apply) as defined by Bloom's taxonomy,[10] did not significantly change in the inverted classroom. However, performance on the two course projects, which they consider to be higher order learning outcomes (analyze, evaluate, create) as defined by Bloom's taxonomy, significantly improved with the flipped classroom approach.

At the University of Cincinnati, approximately twenty sections of Engineering Models I and II are offered each year. The Department of Engineering Education, which is responsible for these two courses, only has enough faculty to cover half the sections so other departments are relied upon to supply instructors. Some of these instructors do not have a great deal of experience with MATLAB or with teaching first-year students. Many of them teach only one semester then are replaced by another faculty member from their department. Thus, every semester there are several instructors that are new to the courses.

There were several reasons that it was decided to implement the flipped classroom pedagogy for Engineering Models I and II:

1. To ensure that students in all sections receive the same basic information regardless of instructor
2. To keep students more engaged during lecture
3. To better prepare students for recitation and homework assignments
4. To give instructors the flexibility to create their own lecture activities

First Year of Flipped Classroom (2013-2014)

The effect of flipping the classroom on student performance, retention, and attitude was presented at the ASEE conference in Indianapolis in June 2014 and will be summarized here[11].

In terms of student performance, the D-F-W rate in Engineering Models I and II dropped in spite of a large increase in enrollment in 2013 as shown in Table 1. From the table, it would appear that the enrollment in Engineering Models II was lower than expected based on the D-F-W rates for Engineering Models I. This is due to the math pre-requisite for Engineering Models II. Students may only enroll in Engineering Models II if they have completed Calculus I with a grade of C- or better or they are enrolled in Calculus I and received a C- or better in Pre-Calculus. The D-F-W rate in Calculus I and Pre-Calculus is typically 25-30%.

Table 1: D-F-W Rates

Engineering Models I								Engineering Models II				
Year	**CEAS Student Total**	**D**	**F**	**W**	**Total**		**Year**	**CEAS Student Total**	**D**	**F**	**W**	**Total**
Fall 2012	816	3.3%	4.3%	4.5%	12.1%		**Spring 2013**	642	3.4%	3.1%	3.4%	9.97%
Fall 2013	1029	2.7%	3.5%	2.9%	9.1%		**Spring 2014**	813	2.8%	3.2%	1.6%	7.7%

At the end of Engineering Models I and II, students were asked to fill out an extensive survey about the course through Blackboard. A good response rate (66.5% in the first course and 81.9% in the second course) was achieved on the survey because it counted as two quiz grades. As shown in Figure 1, 70% of the students in Engineering Models I indicated that they always or often watched the videos prior to attending lecture. However, in Engineering Models II, the percentage of students that always or often watched the videos dropped to 57%.

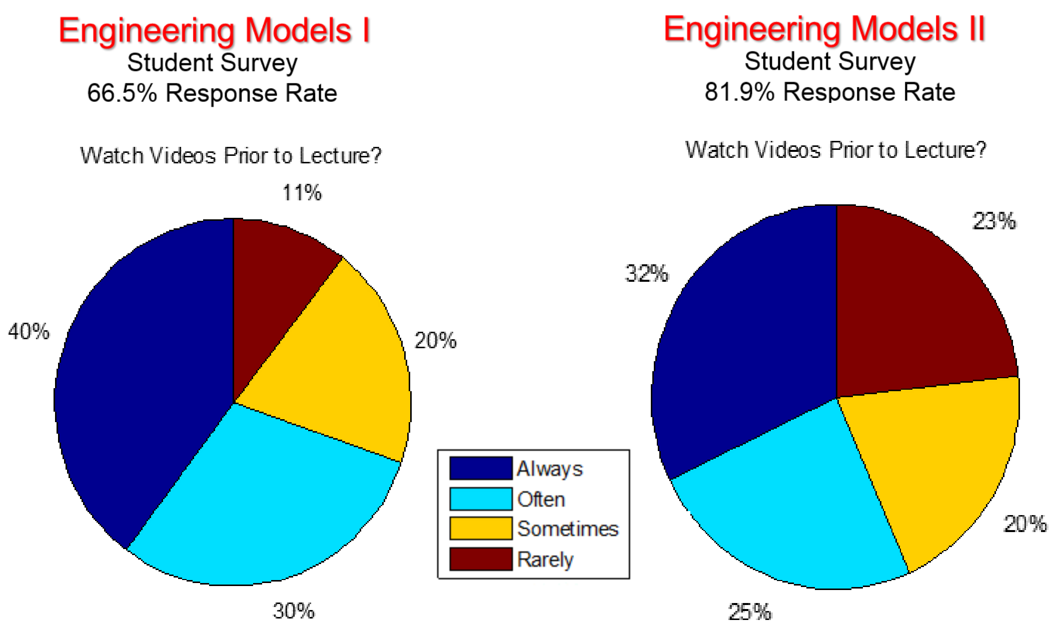

Figure 1: Student survey results on watching videos prior to lecture

In both end of course surveys, most students indicated that the videos were helpful and provided several positive comments. However, in the Engineering Models I survey, 18.3% of the students indicated that the videos were either too long, very boring, or both. Based on this feedback, the videos were shortened for Engineering Models II, which students seemed to appreciate. Only 5.1% of the students commented on the videos being long and/or boring and several indicated that the shorter, more concise videos allowed them to budget their time better. The students that did not watch the videos regularly split into two groups: one group that preferred to read through the PowerPoint slides that accompanied the videos and the other group that apparently did nothing to prepare for lecture.

Student were also asked to comment on the in-class activities during lecture. Survey results indicated that some of our instructors simply reviewed the material on the pre-lecture videos and did not do any active problem solving during lecture. These students understandably felt that lecture was a complete and total waste of their time. They only showed up to take the quiz at the beginning of lecture.

Second Year of Flipped Classroom (2014-2015)

Based on the experience in the first year, the following changes were implemented:

1. Videos for Engineering Models I were shortened either by editing out material or breaking the longer videos into two or three videos. Also, a table of contents was added allowing students to easily find content within the video.
2. An attempt was made to make it clear to instructors that lecture time should be spent doing in-class activities rather than simply repeating the material in the videos.
3. Additional in-class activities and new recitation assignments were developed for loops and arrays since survey data and exam performance indicated these were difficult topics for some students.

This section will describe the effect of these changes on student performance and attitude in Engineering Models I for the fall semester 2014. Student attitudes and perceptions are measured through an extensive course survey at the end of the semester. As mentioned previously, the response rate is quite good since completion of the survey counts as two quiz grades. The results of the survey are anonymous and it is administered through a Blackboard site common to all sections of the course. Students are not asked to identify their section number or professor although many do mention their instructor's name in the open-response questions. Student performance is measured by scores on common final exam problems and final course grades.

Student Feedback on Videos

The end of course survey for Engineering Models I in the fall semester of 2014 had a 75% response rate. As indicated in Figures 2 and 3, it appears that decreasing the length of the videos resulted in an increase in the percentage of students who watched the videos and an increase in the percentage of students that found the videos to be helpful.

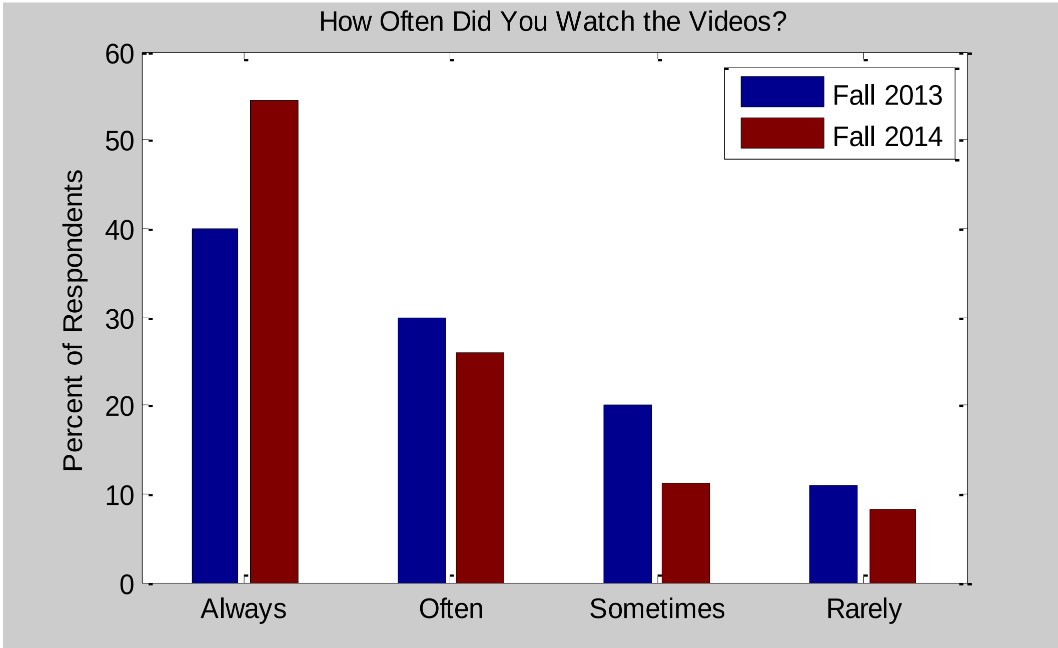

Figure 2: Student Survey – Engineering Models I – Watched Videos?

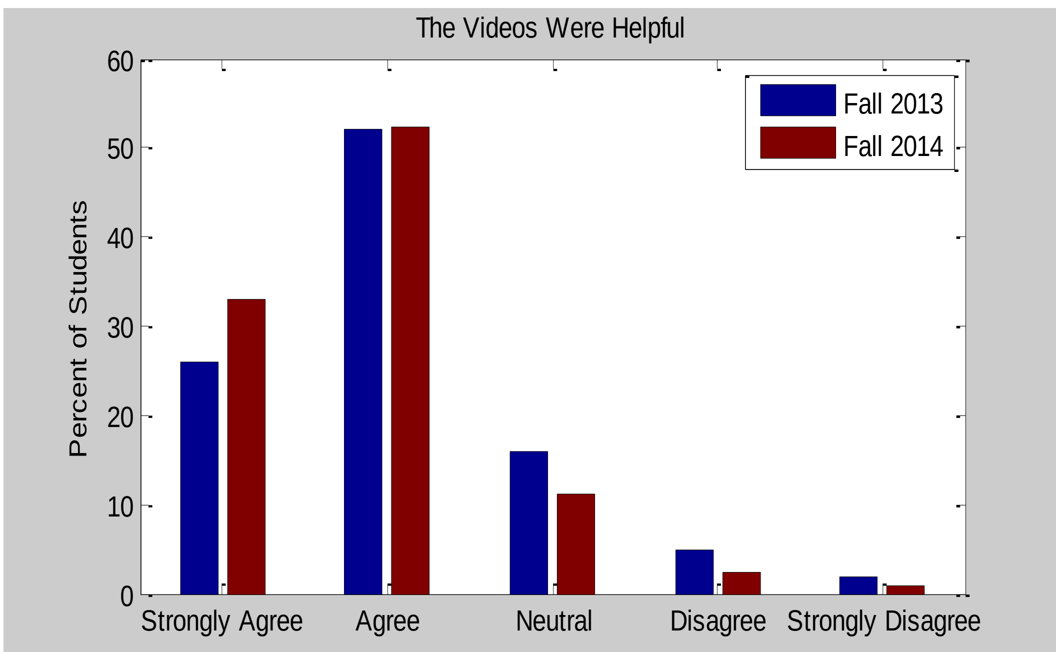

Figure 3: Student Survey – Engineering Models I – Videos Helpful?

Figure 4 indicates that a larger percentage of the female students watched the videos than the male students. This was also true for the 2013 offering of the course.

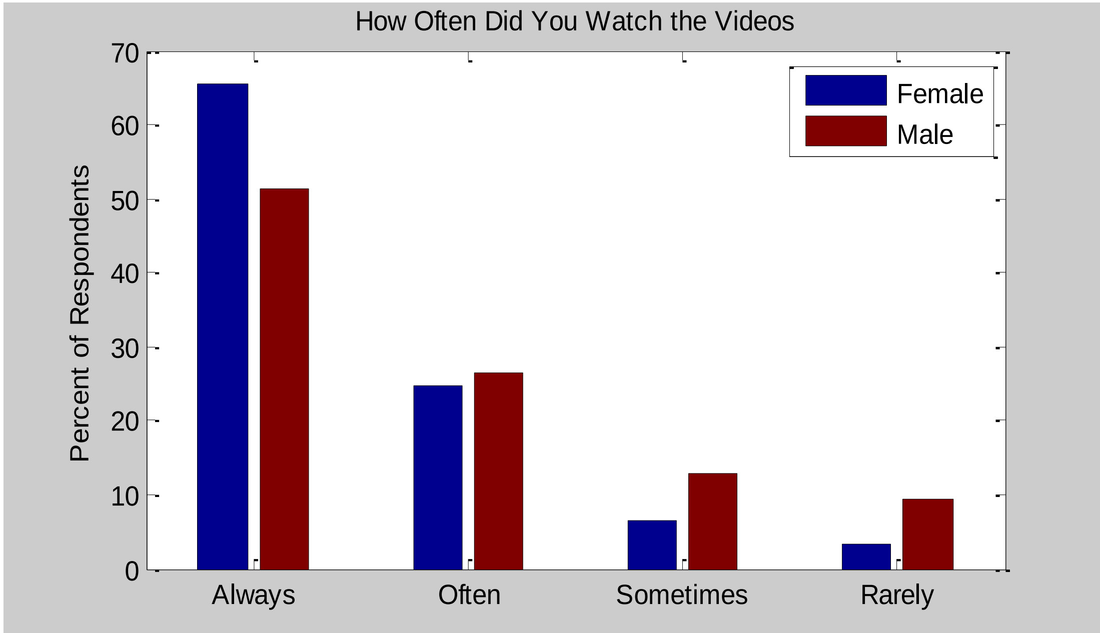

Figure 4: Student Survey – Engineering Models I 2014 – Watched Videos?

Not surprisingly, Figure 5 shows that a smaller percentage of students with prior programming experience watched the videos. Many of these students indicated that they just scanned through the PowerPoints to pick up the syntax differences between MATLAB and whatever language they had already learned.

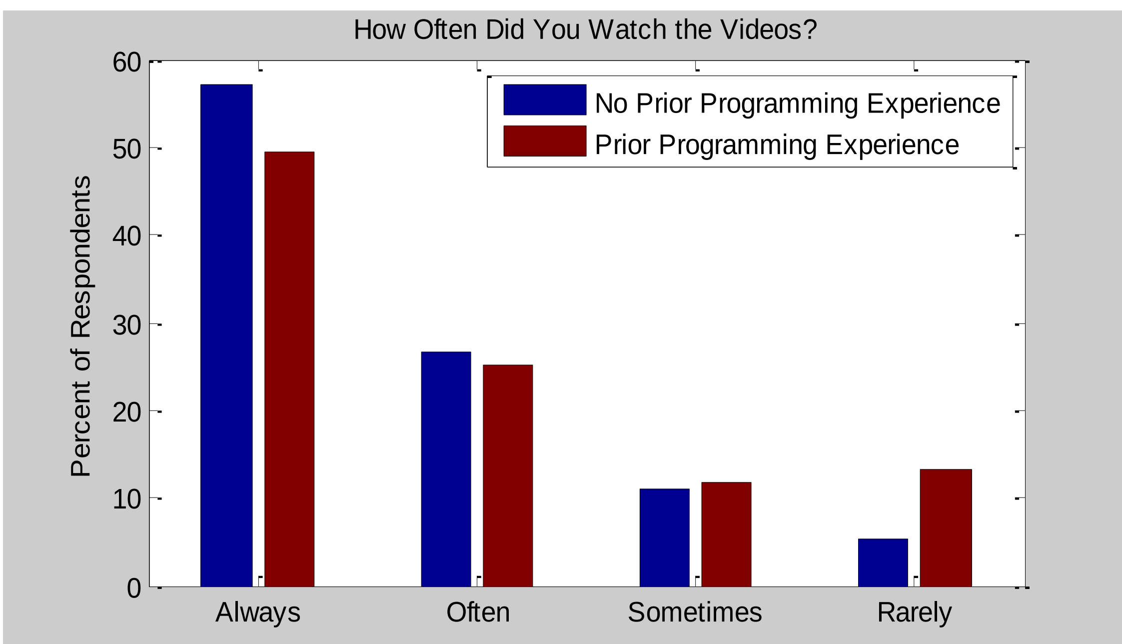

Figure 5: Student Survey – Engineering Models I 2014 – Watched Videos?

The qualitative survey data about the videos indicated that only 6.5% of the students found the videos to be long and/or boring compared to 18.3% in the previous year. Also, students appreciated the fact that the videos provided a good introduction to programming concepts and lecture time was spent working through problems related to the concepts. Of the 77 students that rarely watched the videos, 45 students indicated that they either had prior programming experience or preferred to read the PowerPoint slides accompanying the videos rather than listening to audio explanations, and 6 students indicated that they felt that watching the videos wasn't necessary to help them perform well in the course.

Sample comments from students that watched the videos regularly:

- *"I thought that they were well put together, and it was helpful to be able to watch them, then try exercises, then be able to go to lecture and gain an even more in depth understanding of the course material than just the basics learned in the videos."*
- *"The videos were extremely useful. I felt that class lecture time was able to be used more efficiently and in a more hands-on way to help students further understand the material. Having the base of knowledge from the videos made the lectures much more productive."*
- *"I thought they were very helpful and thorough. The videos also went through many examples that put the material into a real world applications that helped me see the connection between the class and real world engineering."*
- *"I thought that the videos were a great resource to use for the class because they always helped me learn the commands for matlab. The videos were rather boring at times but that would be hard to change. However, I found that it was nice that if i had a question about a command I could always use the vidoes as a resource to learn."*
- *"The videos were easy to understand and very helpful for understanding lecture. I watched them every time and took notes on them, and I could always follow along in lecture. In recitation sometimes I had to refer to my notes, but the information I needed was almost always in there."*
- *"The Videos were absolutely amazing. They are one of the reasons why this is my favourite class. I have had no experience in coding before but I was able to understand everything in one go."*

Sample comments from students that rarely watched the videos:

- *"I found that going through the PowerPoint presentations and taking the practice quiz adequately prepared me for lecture, in less time. I did not watch any of the videos, yet I scored well on the weekly quizzes."*
- *"For the most part, I didn't watch the videos. I have programming experience - to me, essentially all of the material covered in the videos and by the quizzes was simply logical thinking. Matlab functions are pretty self-explanatory to me."*
- *"I didn't watch them too often. Instead I would read through the power points. I like that better because you can read through at your own pace. When I did watch the videos I thought they were informative and helped prepare me for lecture."*
- *"They were sometimes boring and would put me to sleep, but that is hard to avoid on the topic it is showing."*
- *"I have had programming classes before, and didn't need to watch the videos to grasp the concepts. However, I did take the practice quizes beforehand, to make sure i grasped the material, and to make sure I understood Matlab syntax."*

Student Feedback on Lecture Activities

All instructors are provided with a large set of possible problems to work on with students during lecture. Instructors also have the option of creating their own problems related to something that interests them. The survey data indicates that some of the instructors are still not buying into the flipped classroom approach. During lecture, they simply review the basic material covered in the videos rather than actively working with the students to solve more challenging problems using MATLAB. This is a difficult problem to solve because the Department of Engineering Education does not have enough faculty to cover all sections of the first year courses and must rely on other departments to provide some of the instructors. In most cases, instructors from outside the department come in, teach one semester, and then get replaced with someone else the next semester. Unfortunately, Figure 6 indicates that our instructors this fall were less effective in promoting active learning than the year before.

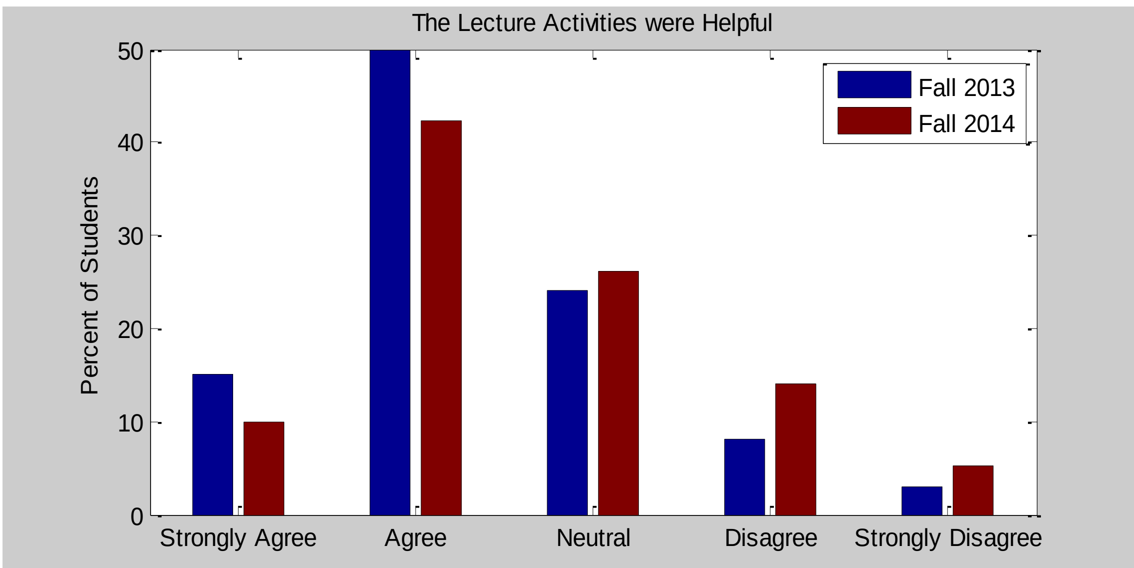

Figure 6: Student Survey – Engineering Models I – Lecture Activities

Sample of positive comments from students on lecture activities:

- *"I found the lecture activities to be very beneficial. They were challenging enough to teach the students, but weren't overbearing. They gave the students a glimpse of what was to come without scaring anyone away. Oftentimes the lecture activities would be very similar to the homework assignments, which was very helpful if I ever got stuck and didn't know what to do."*
- *"The lecture activities were definitely helpful, especially when the professor went really in depth on how to complete them. They allowed us to use our knowledge of what we just learned, and try and understand it more."*
- *"The lecture activities were very helpful because the examples used in the prior videos and sample quiz were very basic and almost common sense. In lecture, it was an opportunity to see the commands be used in various ways and observe the different situations in which they could be utilized."*

Sample of negative student comments on lecture activities:

- *"The videos were helpful however lecture was not. My professor taught us nothing that the video didn't teach us. If I had watched the video prior to class there was absolutely no reason to show up for class except for the quizzes."*
- *"Lecture was a complete waste of time. The teacher read word for word off of his powerpoint slides which we already knew or should have known since we were just quizzed over them. The only reason I attended lecture was because of the quizzes."*

Additional Activities on Loops and Arrays

Additional in-class activities and new recitation assignments were developed this year for loops and arrays since the student survey data and the final exam performance from the previous year indicated that some students struggled with these topics. In order to accommodate the additional lab assignments, the end of semester team project was moved to the beginning of Engineering Models II. The new recitation assignments were designed to help students progress from single loops and one dimensional arrays to nested loops and multi-dimensional arrays.

The end of course survey asks students to list the topics that they found most difficult in the course. In fall 2014, 7.7% of the students included arrays as a difficult topic compared to 14.4% of students in the previous year. However, in fall 2014, 22.2% cited loops as a difficult topic compared to 17.7% in the previous year. The increase in the percentage of students indicating difficulty with loops could be because one of the new recitation assignments involved encrypting a message and hiding it within a 3-d image. In retrospect, the assignment was too complicated for many of our students and 43% of the students indicated on the survey that they disliked that particular lab.

Student Performance in Engineering Models I

The changes made this year had a positive effect on student performance. Table 2 shows the D-F-W rate in Engineering Models I over the last three years. Students are split into two groups: freshmen that are enrolled in programs in the College of Engineering and Applied Science and freshmen that are enrolled in programs in other colleges within the university. In spite of increasing enrollment each year, the D-F-W rate continues to decline.

Table 2: D-F-W Rates in Engineering Models I

College of Engineering and Applied Science (CEAS) Students						**Non-CEAS Students**				
Year	**Students Enrolled**	**D**	**F**	**W**	**Total**	**Students Enrolled**	**D**	**F**	**W**	**Total**
Fall 2012	816	3.3%	4.3%	4.5%	12.1%	174	8.6%	10.9%	14.9%	34.5%
Fall 2013	1029	2.7%	3.5%	2.9%	9.1%	123	3.3%	7.3%	17.1%	27.6%
Fall 2014	1124	2.1%	2.7%	2.0%	6.8%	143	6.3%	8.4%	6.3%	21.0%

Student performance on four problems on the final exam that were common between fall of 2013 and fall of 2014 was also explored. Each problem was worth 12 points. The 2013 and 2014 exam problem scores for four of the instructors were compared. These four instructors have taught Engineering Models I and II since the courses began in 2012. In fall of 2013, these instructors taught 538 of the 1152 students enrolled. In fall of 2014, these four instructors taught 529 of the 1267 students enrolled. A common rubric was used to grade the exam problems. Table 3 shows a significant increase in the mean for all four of the problems indicating that the improvements made to the flipped classroom approach in the redesigned videos and expanded in-class and recitation activities did improve student performance.

Table 3: Performance on Common Final Exam Problems

Problem	Mean 2013	Std. Deviation 2013	Mean 2014	Std. Deviation 2014	Change In Mean	Z Value	Significant $\alpha = 0.01$
P3	8.90	2.37	9.32	2.18	+0.42	4.06	YES
P6	10.09	2.64	10.75	2.08	+0.66	5.77	YES
P7	9.89	3.04	10.76	2.20	+0.87	6.56	YES
P8	7.17	3.13	8.27	2.75	+1.1	8.09	YES

Table 4 lists the topics covered in each exam problem and reflects the increased emphasis an arrays and loops.

Table 4: Final Exam Topics

Final Exam Question	Topic
1	1-d Arrays
2	Basic Statistics
3	2-d Arrays
4	Array Functions
5	Nested Loop and Conditional
6	While Loop
7	Looping and 1-d Array
8	Nested Loop and 2-d Arrays

Discussion and Future Plans

The changes made to Engineering Models I this year had a positive effect on student performance and attitude. More students watched the videos this year and found them helpful. Students performed significantly better on the final exam and the D-F-W rate dropped. The biggest continuing challenge is getting instructors that are supportive of active learning activities during lecture.

To prepare for lecture, students currently have a choice of watching a video or reading through a set of PowerPoint slides. For those students who prefer a hands-on approach to learning, an alternative is being developed. It is an interactive MATLAB GUI with lessons on the topics covered in the videos. The GUI is modeled on the interactive lessons offered by Codeacademy[12] for various programming languages. The plan is to make this GUI available to students in

Engineering Models I next fall and track how many students prefer interacting with the GUI to prepare for lecture instead of watching the videos.

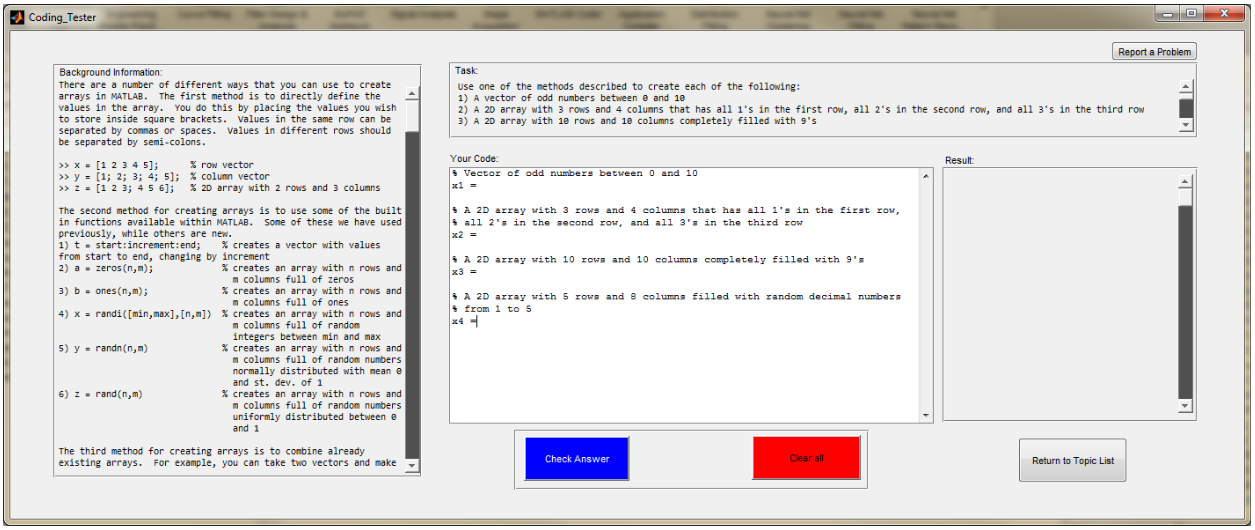

Figure 7: Example of MATLAB GUI Preparation Alternative

For the next offering of the courses, plans are currently being developed to better understand student attitudes towards the flipped classroom approach depending on their experience throughout the two courses. It is quite possible that many of the students who end up not watching the videos come from those sections in which the instructor simply covers the slides from the videos instead of engaging the class in active learning. This would provide additional context when analyzing the results of the end-of-semester survey. Additionally, knowing which sections survey respondents originate from would allow for an analysis of how well the students are performing for sections where the flipped classroom is employed effectively versus those where it is not or where students do not prefer the approach.

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