An Alternative to Videos for Lecture Preparation in a Flipped First-Year Engineering Computing Course

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Abstract

This paper describes an evidence-based practice project. At the University of Cincinnati, two courses, Engineering Models I and II, are offered to all first-year engineering students and form a two-semester sequence in which students apply fundamental theories from algebra, trigonometry, calculus, and physics to relevant engineering applications chosen from a variety of disciplines. MATLAB® is introduced and progressively developed as a computing 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 the basics of programming as well as 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. Throughout the courses, several team projects are introduced requiring the students to use MATLAB® to develop solutions to open-ended design problems.

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. In order to reduce variation between sections, a flipped pedagogy was implemented for the 2013-2014 academic year in these courses. Specifically, videos were created from the lecture material which students watched prior to lecture and lecture time was then devoted to solving problems, either in small groups or as a class.

Through end-of-semester surveys completed by the students, it was found that many students preferred to simply review the provided slides instead of watching the lectures. While the videos do provide additional content not available solely through the slides, they are still a mostly passive way to gain information (there are practice quizzes available, but the videos themselves do not provide much interaction). To cater to those students who did not gain much from the videos, a system was created that is more interactive. The system, dubbed the Engineering Models Practice System, was created in MATLAB and was modeled after the successful online site Codecademy, where students are presented with course content and are asked to complete simple exercises based on this material. The content available in the practice system is the same as that in the videos, but affords students the opportunity to immediately apply the material towards solving simple problems.

This paper will use data from end-of-semester student surveys and performance on course assignments to analyze the effectiveness of the practice system compared to the traditional lecture preparation options.
Introduction

In a flipped pedagogy, the roles of in-class and out-of-class activities are switched. In most implementations, this manifests itself by moving content delivery outside of class, 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 also appreciate the active learning opportunities that the flipped classroom affords. Much of the early research focuses only on student attitudes and perceptions toward the inverted classroom pedagogy.\(^3\)-\(^6\) For example, Foertsch et al used the flipped classroom approach in a computer course for sophomores and juniors.\(^3\) 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. Another more recent study which looked at student attitudes towards the flipped-classroom across multiple institutions showed that while students did recognize some of the benefits of the flipped classroom model, many still preferred at least some amount of traditional lecture.\(^7\)

More recent research has focused on whether or not the flipped classroom has an effect on student learning and performance.\(^8\)-\(^11\) At Harvey Mudd College, a controlled study was performed in selected engineering, science, and math courses.\(^8\) One section of the course was taught using the traditional lecture approach while another section was taught using a flipped approach. There was no significant difference in performance between students in the traditional and flipped sections. At Ohio State, the flipped classroom was implemented in a first-year engineering MATLAB course.\(^9\) 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.\(^10\) They found that student performance on the final exam and basic assignments, which they consider to be lower order learning objectives on Bloom’s taxonomy\(^12\) (remember, understand, apply), did not significantly change in the inverted classroom. However, performance on the two course projects, which they consider to be higher order learning objectives (analyze, evaluate, create), significantly improved with the flipped classroom approach. Another study at Seattle University showed that students performed the same or better than students in a traditional lecture setting even while the instructor moved more quickly through the course material.\(^11\)

At the University of Cincinnati, approximately twenty sections of a two course sequence, Engineering Models I and II, are offered each year. In these courses, concepts from math and science are tied to engineering problems through the medium of computing. These courses were first offered during the 2012-2013 school year and a flipped model was implemented during the 2013-2014 school year. 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

Data collection over the two full years of flipped classroom implementation has shown an improvement in the student performance on the common final exam and a reduction in the drop-fail-withdraw (DFW) rate each year.\textsuperscript{13,14}

Despite the many potential benefits of implementing the flipped classroom model, there are a number of potential pitfalls. The main obstacle is when the technique is not implemented correctly. As was mentioned previously, one of the motivations for implementing the flipped classroom model in the Engineering Models I and II course sequence was to provide some baseline level of instruction. However, as was reported by students in several sections of the course during the 2014-2015 school year,\textsuperscript{14} some instructors simply went over the PowerPoint slides used to create the videos instead of working examples with the class during lecture. This lead to an overall dislike of the approach by the students in these sections as they were frustrated that they were getting repeat information during lecture and saw no reason for why they were being asked to watch the videos.

Another potential drawback of the technique is the method of content delivery outside of the classroom. One of the main draws to this model is that it affords more time during class to engage in active learning activities. Active learning has been shown to benefit students, both in terms of engagement with the course material as well as increased learning.\textsuperscript{15} However, much of the delivery of lecture material is done through videos. While it is possible to create engaging and interactive videos, most instructors do not have the time to develop such videos. This results in the delivery of lecture material still remaining a primarily passive activity, simply replacing an in-person instructor with a digital one. This may be one of the underlying reasons that many have advocated for short videos (maximum of 15 minutes) when implementing a flipped classroom.\textsuperscript{2,14-15}

**The Engineering Models Practice System**

In order to provide a more active and engaging option for students to use in preparing for lecture in the Engineering Models I and II course, a system was created which combines lecture content and short activities into a single package. This system, dubbed the Engineering Models Practice System (EMPS), is a MATLAB App modeled after the successful website Codecademy\textsuperscript{16} which provides learners with text-based information about different program languages and presents them with activities allowing them to immediately apply the concepts.

For the EMPS, information from the videos was transformed into text-based descriptions and simple activities were created to reinforce the concepts covered. It was decided that text-based explanations would be best for the initial version of the EMPS due to the ease with which the text-based descriptions could be implemented (versus loading and playing the videos inside MATLAB) and for compatibility reasons (the activeX control required for playing videos in a
MATLAB GUI is only available on Windows machines). The information for each lecture is stored in a file, which students download off of the Blackboard learning management system and load into the system. This allows the instructors to easily update content without the need to modify the system itself.

At the beginning of the semester, students were introduced to the EMPS during the first recitation period. During this activity, students are first introduced to MATLAB and taken through a series of simple exercises utilizing basic mathematical operations and variables. One of the exercises required the students to download and install the EMPS and run through a simple activity. This ensured that all students had been exposed to the EMPS and that they had some idea of how to use it.

When students first launch the system, they are presented with an opening screen which provides them with instructions for using the system as well as the ability to load in a lecture file, which can be seen in Figure 1. Once a lecture file is loaded, a list of the available topics within the lecture is shown, allowing the user to select a specific topic or to progress through all of the available topics. When the user has made his/her topic decision, he/she clicks the Begin button to proceed to the content portion of the system.

![Figure 1: Engineering Models Practice System Welcome Screen](image)

The content window (see Figure 2) is the main window a user will interact with when using the system. Lecture content is displayed on the left side of the window, with options for both text and graphical content. Once the user has read and understood the content, the task can be
attempted. The task is designed to be straightforward and focus primarily on the concept covered in the current topic. The user types his/her code into the area in the middle of the window and clicks the Check Answer button to execute the code. The system checks both that an appropriate value for the task was computed and that all required MATLAB commands were used. The output of the code (if any) is displayed in the Result area on the right side of the window. Once the user has correctly solved the task, the Continue button appears, allowing him/her to proceed to the next topic. The user also has the ability to return to the previous topic and return to the welcome window to select a specific topic.

Figure 2: Engineering Models Practice System Content Window

At the beginning of each lecture, students take a short quiz covering the information in the lecture preparation materials in order to encourage the students to review the material. Students who choose to watch the videos are able to take a practice quiz on Blackboard. The same practice quiz is incorporated into the EMPS (Figure 3). Students proceed through the quiz, after which they are presented with their results and given the option to retake the entire quiz, only those questions answered incorrectly, or to simply exit the system.
Results

The EMPS was piloted with students in the Engineering Models I course during the Fall 2015 semester. Feedback was gathered through an end-of-semester course survey administered across all sections of the course. A total of 840 responses were received out of a total of 991 students enrolled in the course for a response rate of 84.8%. These numbers are lower than those reported later on for the DFW rates because four sections of the course were taught by one instructor who did not require the students to watch the videos or take quizzes. To ensure that the responses from these students did not skew the data, their responses were removed prior to analysis.

Since the flipped classroom was implemented during the 2013-2014 academic year, around 70-80% of the students report that they either always or often watch the videos prior to lecture. The percentage of students who reported they always or often watched the videos during the Fall 2015 semester was slightly lower at just over 65%. Students reported that they always or often used the EMPS to prepare for lecture at a much lower rate of approximately 16%. While it was hoped that this number would be higher, it is not surprising that many students gravitated towards the videos since using the EMPS requires more effort on the part of the students, as they need to both read the lecture content instead of simply watching the video and also successfully complete the different activities. However, when the percentage of students watching the videos or using the EMPS are combined, the number of students preparing for lecture using one of the two primary methods is consistent with prior semesters. This indicates that some students who may in the past have watched the videos to prepare for lecture instead gravitated towards using the EMPS. These results are summarized in Figure 4.
An alternative way to view the students’ different methods for preparing for lecture is to look at their choice of medium. Figure 5 breaks down the students’ first and second choices for preparing for lecture out of the 4 options available: watching the videos, using the EMPS, reviewing the PowerPoint slides used to create the videos, and simply taking the practice quiz.

Figure 5: Student Preference for Lecture Preparation
Here we can see that it seems like the majority of the students watch the videos and take the practice quizzes as their primary and secondary methods for lecture preparation. This is understandable, since this is the way the course was originally designed: students watch the videos to learn the content and take the practice quizzes to check to make sure they understood the content. However, around 20% of the students stated that they would choose the EMPS as their first choice for preparing for lecture.

Focusing specifically on the students’ expressed first choice for preparation, the responses can be broken down in several different ways. Figure 6 and Table 1 describe the results when the first choice for preparing for lecture is broken out by gender, prior programming experience, and expected grade.

![Figure 6: Gender Differences in First Choice of Lecture Preparation](image)

For each of these three delineations, a chi-squared analysis was performed to determine whether a relationship existed between each preparation method and categorization. In a chi-squared analysis, a null hypothesis of independence is assumed (i.e. preparation choice is independent of gender) and is rejected if the chi-squared value is more extreme than a given threshold level, expressed as the p-value. For example, if a level of 0.05 was set as the threshold for rejecting the null hypothesis and the analysis returned a p-value of 0.1 (the chi-squared value was larger than only 90% of the possible values) the null hypothesis would not be rejected. If on the other hand, a p-value of 0.01 was computed, the null hypothesis would be rejected and the two categories are dependent. For all chi-squared analyses in this paper, a level of 0.05 was chosen for null hypothesis rejection.

In Figure 6, we see that regardless of the way the data is categorized, the most widely preferred method for preparation was watching the pre-lecture videos. This aligns with the previous
results. For women, a larger percentage (~77%) favored using the videos and the EMPS when compared to their male counterparts (~67%). In terms of students’ prior experience with programming, a higher percentage of students who had prior experience preferred using the practice app whereas those with no prior experience had a higher percentage reported preferring the videos.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Female</th>
<th>89</th>
<th>41</th>
<th>15</th>
<th>23</th>
<th>6.48</th>
<th>0.091</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>299</td>
<td>152</td>
<td>76</td>
<td>140</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Experience | Prior | 153 | 86 | 33 | 64 | 5.27 | 0.153 |
| No Prior   | 253   | 108 | 59 | 99 |    |       |       |

| Expected Grade | A | 273 | 136 | 61 | 103 | 5.78 | 0.449 |
| B            | 105 | 51  | 27  | 55 |    |       |       |
| C            | 9   | 7   | 4   | 5  |    |       |       |

The last way the data was broken out was by anticipated grade in the course. Unfortunately, since the surveys were anonymous, there was no way to tie the survey results directly back to the course performance of the respondents. However, students were asked to identify their expected grade in the course, which was used to explore the preparation preferences of the students.

This final categorization produced the largest variation in responses. Students who expected to receive an A in the class expressed preference for the watching the videos and for using the EMPS, though to a lesser extent. For those students who expected to receive a B in the class, both the percentage of respondents preferring the videos and EMPS dropped while simply reviewing the PowerPoint slides gained in preference. Lastly, those students expecting to receive a C in the class reported the lowest preference for the videos (36%) but the highest for the EMPS (28%) and quizzes (20%). This is an unexpected result, as it was anticipated that students who found the lecture videos too passive would instead choose to use the EMPS, and that these students would be the better students in the class looking for more of a challenge. Instead, it appears that the EMPS was the choice of those students who were struggling in the class and perhaps were not able to learn the material by viewing the videos.

However, when the results of the chi-squared analysis are considered, the null hypothesis in each case could not be rejected. This means that the preferred method for preparing for lecture was independent of gender, prior experience, or expected grade. The closest to being rejected was for
gender, which reached a p-value of 0.09. This, however, was still almost twice the level needed to reject independence.

Students were also asked to comment on why they responded as they did to the questions about the EMPS. Those who always used the EMPS to prepare for lecture and strongly agreed that it was effective highlighted that it allowed them to immediately apply what they were learning to solving simple problems:

“I used the practice system every time it was available, because being able to personally use the commands, and having to think about how they were used ahead of time definitely gave me a fuller understanding of how to use the commands involved than just watching someone else use them in the videos.”

“The practice app was very useful and I responded well to the hands-on learning strategy. Part of what drew me to engineering as a major and a career is that I learn best while doing. The practice app had a good balance of reading information and applying concepts.”

Another benefit students identified was that it allowed them to go through the material at a pace that was comfortable to them. Some students already had experience with MATLAB, and the EMPS allowed them to quickly review concepts and syntax:

“Preferred the practice app because I have a background in matlab. Having the option to just use the practice app before class as a review of the material rather than watch the whole video was really nice.”

Others simply appreciated that opportunity to proceed at their own pace instead of at whatever speed the material was covered in the videos:

“This let me go at my own pace and practice what I was learning while I was learning it.”

“The models practice system app is great. I prefer it to the videos. It is self paced and great for actually understanding what we working on.”

Most of the people who responded that they disagreed or strongly disagreed about the effectiveness of the EMPS either had chosen not to use the system, instead choosing to watch the videos, or primarily focused on technical issues with getting the EMPS to run on their computers or on simply not understanding how to use the system:

“I was confused as to how to use this app. It never really worked for me so i never used it.”

“I couldn't get the Practice System to work so I watched the videos instead.”
However, several students brought up issues that did bring to light some problems with the EMPS. For instance, many students said that they stopped using the EMPS because it would not let them advance to the next topic without completing the current activity. If they got stuck and couldn’t figure something out, there was no help given and no way to proceed:

“In the practice app you could get absolutely stuck because you didn’t know what you were doing, it needs a show me or tutorial so that you don’t get stuck with no other option than to exit out.”

“I tried it twice. I found it hard to trouble shoot [the activities] without a TA, and you can’t advance or get the next explanation without it. Maybe I should have given it another chance, but I had success with the videos and so didn’t bother.”

“The app was helpful at some times but the way it is set up doesn’t let you go back to look at the previous page without exiting the chapter. There were times when I got stuck and felt like I could not move forward or backward.”

Table 2 shows the breakdown of the responses for students using the EMPS to prepare for lecture and how effective they felt it was in doing so.

<table>
<thead>
<tr>
<th>Used EMPS?</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Applicable</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>38 (70.4%)</td>
<td>14 (25.9%)</td>
<td>2 (3.7%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>54</td>
</tr>
<tr>
<td>Often</td>
<td>28 (36.4%)</td>
<td>42 (54.5%)</td>
<td>4 (5.2%)</td>
<td>2 (2.6%)</td>
<td>0 (0%)</td>
<td>1 (1.3%)</td>
<td>77</td>
</tr>
<tr>
<td>Sometimes</td>
<td>13 (9.4%)</td>
<td>72 (51.8%)</td>
<td>45 (32.4%)</td>
<td>8 (5.8%)</td>
<td>1 (0.7%)</td>
<td>0 (0%)</td>
<td>138</td>
</tr>
<tr>
<td>Rarely</td>
<td>2 (0.35%)</td>
<td>33 (5.8%)</td>
<td>235 (41.6%)</td>
<td>43 (7.6%)</td>
<td>15 (2.7%)</td>
<td>237 (41.9%)</td>
<td>550</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 637.6355, \text{P-value} = 0.000 \]

As can be seen, the majority of the students rarely used the EMPS in preparing for lecture and consequently were either neutral about using it or indicated they were not in a position to rate its effectiveness. Additionally, as the usage of the EMPS for lecture preparation increased, there was a shift from negative views of its effectiveness towards positive views of its effectiveness. Of those reporting that they always used the EMPS, 96.3% of respondents had a positive viewpoint. That percentage drops to around 91% for those who often used the EMPS and to around 61% for those that sometimes used it. The results of the chi-squared analysis indicate that there is a relationship between use of the EMPS and perceived effectiveness. This makes sense, since using the EMPS was optional and only those who felt that it was a better method for preparing for lecture would choose to use it. Likewise, people would not choose to use the
EMPS if they found that it was not an effective method for their preparation (as seen by the shift from positive to negative views as usage decreased).

Since the inception of the course in the fall semester of 2012, the effects of changes in the course have been monitored by tracking the DFW rates. Previously reported results showed that implementing the flipped classroom,\textsuperscript{13} reworking the videos, and improving the instructions for the instructors\textsuperscript{14} have had a positive impact by reducing the DFW rates. For the Fall 2015 offering of the course, the only major revision was the introduction of the EMPS. As can be seen in Table 3, the DFW rates for those students in Engineering Models I who are from the College of Engineering and Applied Science (CEAS) dropped again for the Fall 2015 offering. This is a very positive sign, as the CEAS population includes students in the Engineering and Applied Science Entrance (EASE) program, which is for students who are close to meeting the entrance requirements for CEAS but do not meet them (typically due to Math ACT scores). This group typically does not do well, especially in the introductory math courses, and students often end up transferring to other colleges. If the DFW rates for this group are isolated, a similar, and much more dramatic trend appears. In 2013, the DFW rate for EASE students was 26.8%. This dropped to 19.2% in 2014 and to 8.3% in 2015. The overall population of EASE students has remained roughly the same over this period, implying that the changes made to the course are helping those students who would normally struggle in the course.

<table>
<thead>
<tr>
<th>Year</th>
<th>Students Enrolled</th>
<th>D</th>
<th>F</th>
<th>W</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall 2012</td>
<td>816</td>
<td>3.3%</td>
<td>4.3%</td>
<td>4.5%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Fall 2013</td>
<td>1029</td>
<td>2.7%</td>
<td>3.5%</td>
<td>2.9%</td>
<td>9.1%</td>
</tr>
<tr>
<td>Fall 2014</td>
<td>1124</td>
<td>2.1%</td>
<td>2.7%</td>
<td>2.0%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Fall 2015</td>
<td>1097</td>
<td>1.6%</td>
<td>2.3%</td>
<td>1.7%</td>
<td>5.7%</td>
</tr>
</tbody>
</table>

**Discussion and Future Plans**

In the first deployment of the Engineering Models Practice System, 23% of the students chose it as their preferred method for preparing for lecture. Students who chose to use the EMPS were very positive in their response to it and appreciated the alternative method for preparing for lecture. The most often voiced reason for using the EMPS over the other methods of watching videos or reviewing PowerPoint slides was that it provided for a hands-on and self-paced approach to lecture preparation.

Despite the positive reaction, there were several issues with the system. Based on the feedback received during the pilot run of the EMPS, the following changes have been made to the EMPS for future offerings of the course:

- **Easier navigation between topics:** a button was added to the content window that brings up a list of the topics available within the current lecture, allowing the student to easily switch between topics or return to previously viewed topics.
• **Hint and solution availability:** two buttons were added to the content window that appear once the student has attempted an activity several times. After two unsuccessful attempts to solve an activity, a hint button appears that, when pressed, provides the student with some guidance as to what might be causing the problem. After a third unsuccessful attempt, a solution button becomes visible which, when pressed, populates the code area with a correct solution to the problem.

• **Better explanations of errors:** while the EMPS provides students with feedback on errors produced by MATLAB, it also informs students if they did not use a required element to solve a given activity (for example, if the problem required them to use a for loop and a while loop was used instead). The version of the EMPS deployed simply stated a required element was not used. This feedback was modified to specifically state what element was not used in the solution. Providing context specific feedback to students is a future goal, but will require significant development in order to implement.

• **Better instructions for using the EMPS:** a user manual was created and is now accessible within the EMPS by clicking on the Help Document button. This button is present in both the welcome screen and content window.

Screenshots of the updated version of the EMPS are shown in Figures 7-9.
While the results discussed in this paper show that the EMPS was beneficial in helping a sizable percentage of the students to better prepare for lecture, the paper is limited in that the survey results are anonymous. While the students were asked to report their expected grade in the class, being able to link the students’ actual final grades to their choice of lecture preparation would help in showing whether the EMPS helped to improve performance.
An additional limitation of the study is the variability in terms of instruction. Given the large number of sections of the course, there were 11 different instructors teaching the course during the Fall 2015 semester. Some instructors did a good job of utilizing the flipped classroom approach and encouraging students to prepare for lecture while other instructors were less effective. We have seen previously\textsuperscript{13,14} that when an instructor does not follow the flipped classroom model, the students are understandably frustrated and often neglect to complete the lecture preparation. While this issue was less prevalent during the Fall 2015 semester than in previous semesters, it still may have impacted the results reported in this study.

**Bibliography**