Applying the Flipped Learning Method in Engineering Courses by Using Web Based Tools: An Innovative Approach

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Abstract— **The flipped learning method requires students to view basic theory and material before entering the classroom. This leaves adequate time for the professor to interact with the students during in-class problem solving sessions. This concept of a flipped classroom is not new; it is the authors' assumption that many professors currently ask students to read material in order to prepare for upcoming classes. However, confirming that the material has been reviewed by the students may be difficult and time consuming.**

The widespread use of computers and the internet now introduce creative ways to deliver pre-lecture material while ensuring that the students have completed the pre-lecture assignments before coming to class.

This document explains a method that is currently being used in MECH-310 (Dynamics). The students are required to view pre-lecture videos before entering the classroom. The pre-lectures have been created by combining a LiveScribe™ Pen and TechSmith Camtasia® screen capturing software.

The results of anonymous student surveys and final exam scores verify that this method is effective and well accepted by students.

Index Terms—**Flipped Learning, Active Learning.**

Introduction

The main reason for the flipped learning approach is to support interactive learning in the classroom. In this setting, the professor can serve as more of a "coach" or "mentor" to the students, because the basic and necessary theory has already been viewed and generally understood by the students before they attend class.

There is documentation that interactive learning provides an environment that enhances a more useful understanding of the material [1]. Also, plain lecturing has not been found to be effective for helping students reach the higher levels of learning [2][3][4].

In a recent study, the instructor observed an increase in student attention to the coursework compared with other courses taught in a more traditional manner by using the flipped learning approach. Most importantly, post-test scores of the flipped classroom exceeded those of a traditional approach [5]. Other studies report the same basic conclusions [6][7][8]. In 2015, a comprehensive literature review regarding flipped learning was conducted. It was concluded that students prefer the flipped classroom because they have the flexibility to learn new concepts on their own time while having the chance to interact with the professor in the classroom [9].

II. Course Structure

The structure of MECH-310 is based on Course Learning Objectives (CLO's), which are in-line with ABET criteria for course assessment. There are four CLO's in MECH-310. These CLO's contain 16 sub-CLO's. The final examination is comprised of exactly one problem per sub-CLO. For example, CLO #1 of MECH-310 has five sub-CLO's:

CLO 1: Analyze the kinematics of a particle in order to predict its motion in 1-D and 2-D coordinate systems

1.1 Rectilinear (1-D) Motion
1.2 Motion in the Cartesian coordinate system
1.3 Motion in the normal-tangential coordinate system
1.4 Motion in the cylindrical coordinate system
1.5 Relative motion between two particles

The course content is driven by the CLO's. The pre-lectures are labeled by CLO and not by "chapter". Although this may appear to be a minor issue, the course structure provides students with their specific responsibilities throughout the term. (The CLO's are, in general, mapped directly to the chapters and sections within the textbook.)

A set of pre-lectures was provided to the students about three days before each lecture. The pre-lectures are short video clips of the professor explaining course material, which is similar to explaining theory on the chalkboard. One advantage of pre-lectures as compared to in-class chalkboard lectures is that the students can pace themselves, as needed (i.e. students can speed up, slow down, or pause the videos). The pre-lectures were used to explain the basic material that was to be covered in the following lecture. This enabled the instructor to work with the students in the form of a "coach" in the classroom setting. Classes were almost exclusively interactive and concentrated on solving practical engineering problems. A sample

screenshot of the final frame of a pre-lecture is shown in Fig. 1.

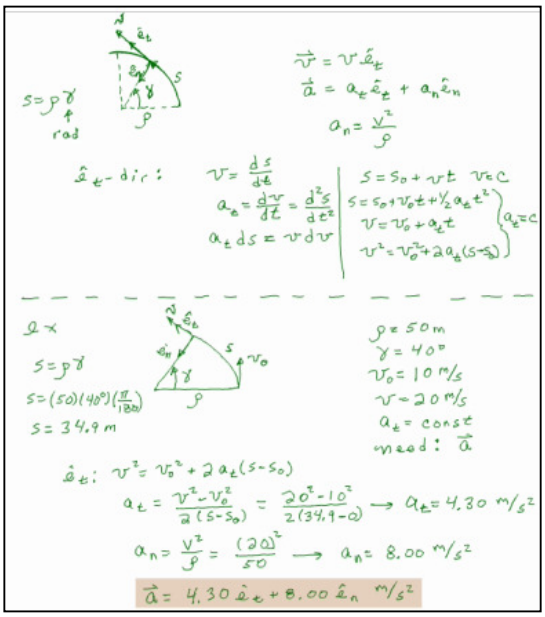

Figure 1. CLO 1.3 Sample Screenshot

The pre-lectures were created by capturing the writing with the LiveScribe™ digital pen. The voiceovers and dubbing were then done by utilizing TechSmith Camtasia® software. A goal was to keep all pre-lecture videos "on-target", with time limits of approximately 7 minutes per video and a 20 minute review per in-class lecture.

III. ASSESSMENT

The assessment is divided into three categories (Instructor Perceptions, Student Perceptions, and Impact on Grades).

A. Instructor Perceptions (Formative Assessment)

The following is the progress of process improvement made throughout the term. Based on instructor perceptions, the formative assessment provided opportunity for improvement in the first offering of the flipped course.

- In order to promote active learning, students were assigned problems to solve in teams of 2 to 4 individuals throughout the term. The professor was available to guide and coach when questions arose. The interaction of the students was extremely impressive from the author's viewpoint. The students unanimously approved of this approach (by hand count in class). However, there was no direct evidence that the students actually viewed the pre-lectures at this point in the term.
- In order to ensure that the students viewed the pre-lectures, elementary quizzes were given in Blackboard. This is referred to as "the stick". Based on observations in the classroom, it was clear that several students viewed the quizzes only to pass the quizzes and not to comprehend the material.
- During the middle of the term, pre-quizzes were no longer required. Instead, a "deal" was made with the students. Several problem statements were presented to the students at the beginning of each class. The number of problems ranged from 2 to 3. No lecture was given and the students were required to solve the problems in groups, with the assistance of the instructor (if needed). The students were allowed to leave the class once all problems were solved correctly by all group members. This provided an incentive; students who took the time to really understand the material via the pre-lectures had the opportunity to get out of class early. This also gave the opportunity for the professor to assist struggling students who may not finish early. This is referred to as "the carrot".
- Several students had the opinion that a brief lecture of the basic material would be beneficial before the in-class problem solving sessions. Therefore, an initial brief 10-20 minute overview of the pre-lecture material was incorporated into the model. The students unanimously approved of this approach (by hand-count in class). It is important to note that students were not asking for complete review of the pre-lecture; they just wanted a brief overview of the material.

B. Student Perceptions (Quantitative Assessment)

The following are the results of a survey of the students, which was completed during the last week of the term. The students were assured that the results of the surveys would remain completely anonymous. A significant number of students (36 out of 50) in two sections of MECH-310 completed the survey (72%).

According to the figures shown on the following page:

- About 86% of the students surveyed were in favor of the flipped-learning approach (Fig 2).
- About 75% of the students surveyed were in favor of pre-lecture quizzes (Fig. 3).
- About 89% of the students surveyed were in favor of using the pre-lectures as an incentive to leave class early (Fig. 4).
- About 86% of the students surveyed believed that the pre-lectures are effective study tools for examinations (Fig. 5).
- About 83% of the students surveyed thought that the pre-lectures have a potential for a deeper understanding of the material (Fig. 6).

In summary, students were in favor of the flipped learning approach and the pre-lecture quizzes ("the stick"). The pre-lectures served as an effective study tool and enhanced a deeper understanding of the material. Also, leaving class early (once the material was understood) was widely accepted ("the carrot").

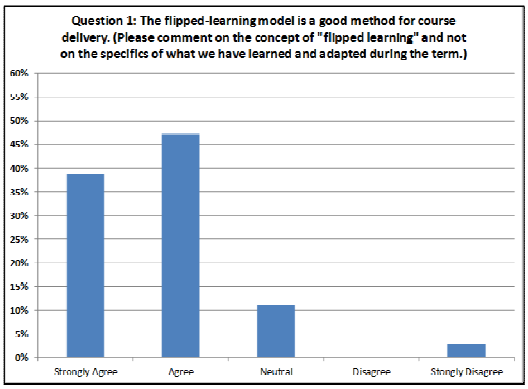

Figure 2. Survey Results: Question 1

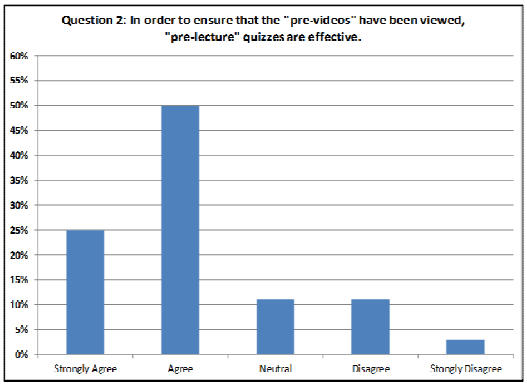

Figure 3. Survey Results: Question 2

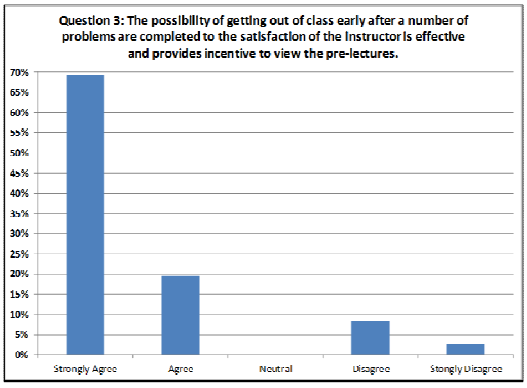

Figure 4. Survey Results: Question 3

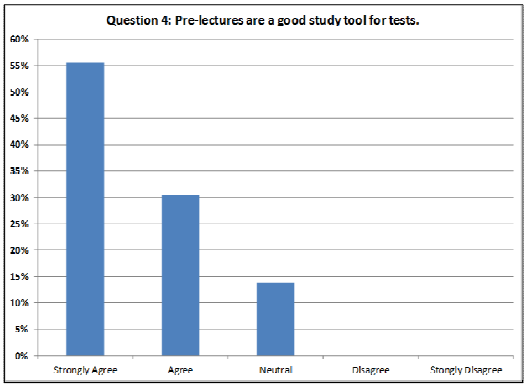

Figure 5. Survey Results: Question 4

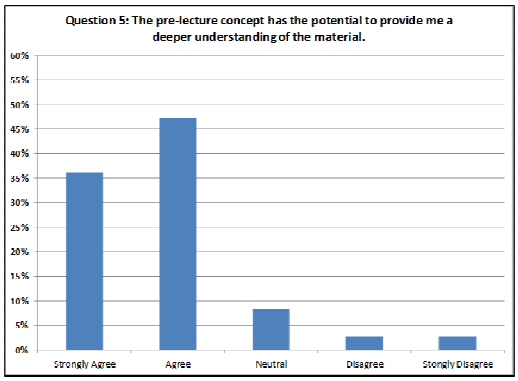

Figure 6. Survey Results: Question 5

C. *Student Perceptions (Qualitative Assessment)*

Below are some selected comments of students regarding the flipped learning approach.

"I really enjoy the pre lectures since they give me a chance to understand the material and problems at my own pace and to work out some questions for when I get to class. They work better when we just have a few problems to do in class that are similar, but ask for different things, then the practice problems. Getting a chance to look over the material ahead of time has made it easier to go over the material, making class the process of proving we understand what is asked of us and getting help if we need it. Therefore letting us leave class early if we are moving quicker without having to spend time while a few aren't."

"The pre-lecture videos were very helpful to me because I was able to go back and watch the videos if I did not understand something fully. They were also helpful later on in the term if I forgot something I could go back and review a topic from a few weeks ago."

"I really appreciate this style of learning because it allows me to start thinking about the material before I get to class. Often, in other courses, when I hear material for the first time in lecture I have to go home and essentially re-teach myself the material because it's difficult to retain all the information. However, with this method, I find the information sticks and I learn the material with a lot less effort on my part. I recommend the continuance of this style of learning in future courses."

"The pre lectures work great! They often help out with homework assignments as well as a great review on what we have learned in previous classes. I find it very beneficial as well, when working on the pre lectures before class in order to grasp the concept and application better when in class."

According to the above, the flipped-learning approach was well accepted by the students. Also, there were no derogative comments in the survey.

D. Impact on Grades (Quantitative Assessment)

Final examination scores of two terms were compared. In order to obtain a direct relationship, an identical final exam was used in each case. A total of 62 students in two sections attended during the previous term (when flipped learning was not used) and a total of 50 students in two sections attended during the winter 2013 term (when flipped learning was used).

It is not common practice to deliver duplicate final examinations in separate terms. However, careful measures were taken in order to assure that the final examination used in this study was not available to the students. Specifically:

- A set of over a dozen previous final examinations are openly available to the students every term; the final examination that was used in this study was not available to the students.
- Final examinations are generally not handed back to the students. The final examination that was used in this study was not handed back to any student.

Following are the results of the final examination scores:

- Final examination scores increased an average of 10.2% when the flipped learning approach was used.
- Each final examination is comprised of exactly one problem per CLO. There was an increase in every CLO (except one) when the flipped learning approach was used. The range of difference per CLO (or problem) was -5.4% to 30.5%.

IV. Conclusions and Observations

1) The goal of the flipped-learning approach is to enable the professor to act more as a mentor than a lecturer in the classroom.
2) The flipped-learning approach was widely approved by students and is a good tool for students to gain a more complete overall understanding of the material.
3) The pre-lecture method of delivery is effective. There were no student complaints regarding:
   a. The LiveScribe pen/Camtasia delivery method.
   b. The length of the pre-lectures.
   c. The content of the pre-lectures, in general.
4) It is the author's opinion that both a "carrot and stick" approach should be used to ensure that the students have viewed the pre-lectures. (This is supported by the qualitative survey and an in-class hand count.) "The stick" involves pre-lecture quizzes. "The carrot" gives the students to possibility leave class early, once the material has been understood.
5) There was a significant improvement in final examination scores when the flipped learning approach was used.

Acknowledgment

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References

[1] H. Roberta, "Beyond Learning Styles: Understanding the Learning Processes of Engineering Students through the Interactive Learning Model™", Proceedings of the American Society for Engineering Education Annual Conference & Exposition, 2004

[2] R.M. Felder, D.R. Woods, J.E. Stice, and A. Rugarcia, "The Future of Engineering Education: Teaching Methods That Work." *Chemical Engineering Education* 34(1), 26-39, 2000

[3] B.S. Bloom, "Taxonomy of Educational Objectives", Longman, New York, 1956

[4] B. Swartz, "Building a Classroom Culture that Paves the Way to Learning", ASEE Paper # AC 2012-3646, 2012

[5] C. Papadopoulos and A.S. Roman, "Implementing an Inverted Classroom Model in Engineering Statics: Initial Results, ASEE Paper # AC 2010-1868, 2010

[6] J. Laman, M. Branno, and I. Mena, "Classroom Flip in a Senior Level Engineering Course and Comparison to Previous Version", ASEE Paper # AC 2012-4028, 2012

[7] S. Zappe, Et. Al, "Flipping the Classroom to Explore Active Learning in a Large Undergraduate Course", ASEE Paper # AC 2009-92, 2009

[8] J. Thomas and T. Philpot, "An Inverted Teaching Model for a Mechanics of Materials Course", ASEE Paper # AC 2012-4331, 2012

[9] S. B. Velegol, S. E. Zappe, and E. Mahoney, Thomas, "The Evolution of a Flipped Classroom: Evidence-Based Recommendations", ASEE Advances in Engineering Education, Winter, 2015

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