Flipping the Engineering Classroom: Results and Observations with Non-Engineering Students

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Flipping a classroom is an innovative teaching method in itself. This method faces additional challenges when the students are not actually engineering majors. The purpose of this paper is to discuss the development, implementation, and assessment of a flipped classroom for a thermal-fluids course for non-engineering majors.

Problem solving is a critical component of engineering education; an engineering student cannot only read problem statements or solely attend a lecture. However, duration of student contact in the classroom is constrained by credit hours. In a local survey, most students indicated that they would not take the time to complete not-for-grade problems on their own after class. For many of these students, graded homework assignments are the first and only experience they have in solving complex engineering problems prior to exams. By only receiving lectures and struggling to work homework problems individually, it is arguable that few of these students are able to progress beyond the lower tiers of Bloom’s taxonomy. Historical time survey data suggests that the students conduct little to no daily preparation when there are no graded requirements and conversely show extremely large time spikes when out of class assignments are due or prior to in-class evaluations. Finally, in-class lectures force an instructor to teach a certain amount of material in a limited timeframe irrespective of the rate at which each student can retain or comprehend that information regardless of the experience level of the student.

Inspired by the pedagogical concept of ‘flipping the classroom,’ Khan Academy online instructional videos, and the Thayer Method (whereby students prepare prior to class, recite the topic to their instructors and receive daily evaluations) the authors created a blended course. This blended course leveraged the digital age through video lectures before class and combined it with traditional engineering problem solving in class. The goals of this blended course are as follows: improve the quality and efficiency of student learning by conducting lectures outside of class and homework during class; allow non-engineering students to learn each lesson’s material at their own pace and provide a valuable study tool for exam preparation; increase the time spent in classroom solving problems with instructors; leverage one-on-one time in the classroom where the instructor can better approach each individual’s issues; encourage and enable non-engineering students to take more responsibility for their learning and become lifelong learners; and inspire intellectual curiosity in the field of engineering. The instructors developed a preliminary beta test for the initial third of an undergraduate introductory course in thermal-fluid systems and kept the remainder of the course unchanged from its traditional lecture method to gain student feedback. This feedback was used to develop a completely blended course consisting of non-engineering majors; the results of which are studied and presented in this paper.
Introduction:

At the United States Military Academy (USMA), all students are required to either successfully complete an ABET-accredited major in one of the offered engineering disciplines or complete a three-course core engineering sequence. The rational for this requirement is simple: a leader’s ability to understand and shape the physical world “can both enhance and constrain a leader’s ability to influence the action of people” and “engineering is the process of shaping the physical world to further human goals.” [1] The belief is that graduates who have studied engineering are well prepared to solve problems when confronted with complex, ambiguous situations that require the need to articulate requirements and constraints and formulate solutions.[1]

Problem Statement:

Students taking a three-course core engineering sequence have various academic majors ranging from foreign language to law, history, and even physics. Due to schedule conflicts, the second course in their mechanical engineering core sequence, ME350 Introduction to Thermal-Fluid Systems with Army Applications is limited to a 3.0 credit hour course in order to facilitate the students’ extremely diverse and already full academic schedules. By comparison, the similar course taken by engineering majors, MC311 Thermal-Fluid Systems I which actually covers fewer topics but in greater depth is a 3.5 hour double-blocked course. (Engineering majors continue on to MC312 Thermal Fluid Systems II for an additional 3.0 credit hours and cover far more additional topics including those covered in ME350.)

Historical time-on-task data collected from students as part of the course and from the program assessment system often reveal that the majority of these students conduct little or no daily preparation when there are no graded requirements due. By contrast, the student time data indicates large spikes in effort when out of class assignments are due or prior to in-class examinations [Figure 1]. [2]
Figure 1: Time-on-task data, representing student preparation outside of class, in minutes. Student report data anonymously. The solid line with diamonds demonstrates large spikes, prior to graded events, exceeding the Dean’s guidance of 120 minutes of preparation per class per lesson.

The data in Figure 1 implies at least two possible behavioral trends. First, some students may not be taking responsibility for their learning, subsequently waiting for information to be presented to them for the first time during lectures. Second, the time data suggests that some students may struggle with out-of-class requirements, often the night before an assignment is due. With no access to an instructor for assistance, these students may be spending more time than necessary to complete an assignment. Courses with a broad range of topics in a single semester, such as course in thermal sciences, often require a large portion of class time for theory development through lecture, leaving little time for in-class student work and problem solving.[2]

Problem solving is a critical component of engineering education. Most engineering students cannot achieve subject mastery by reading problem statements or attending lectures. However, there is usually not enough time to do both in a single class period. It is, therefore, safe to say that the same holds true for non-engineering students. Typically, the in class lectures require an instructor to teach a certain amount of material in a limited timeframe irrespective of the rate at which each student can retain or comprehend that information. To enable efficient problem-solving and application of theory, many courses at USMA provide a study guide to students with an array of optional sample problems. However, in a recent survey, most students indicated that they would not take the time to complete the problems that are not required for their grade on their own, after class, due to competing interests both academic and personal [Figure 2]. For many these students, graded homework assignments are the first and only experience that they have solving complex engineering problems prior to exams. [2] By only receiving lectures and struggling to work homework problems individually, it is arguable that few students are able to gain an appreciable knowledge of the physical world or apply an organized engineering problem solving process that they will need as future leaders.
In an effort to address this problem, the authors studied and leveraged what they considered to be the benefits of three major pedagogies, and apply them within the constraints of the program. The first pedagogy was that of ‘flipping the classroom’ which has become popular within the educational community. In this pedagogical methodology, class work is done at home and homework is done in the class. This resurgence is due in large part to the popularity and success of online instructional videos by Salman Khan, the founder of the Khan Academy. In the Khan Academy model, students are required to watch video lectures independently and complete exercises to evaluate the students’ understanding of the topic. Once the student achieves mastery of a topic, he or she moves on to the next topic in a self-paced learning model, with students advancing independently of one another. [2] Due to graduation timeline requirements, however, a completely self-paced model was not feasible.

The second pedagogy examined was that of the traditional ‘Thayer Method’ from United States Military Academy. Named after Colonel Sylvanus Thayer, the father of the Military Academy, the Thayer Method required students to prepare for class individually and then to recite topics to their instructors who would, in turn, evaluate student performance every day. Students were grouped by ability in order to provide “each student a task of study proportional to his capacity.” [3] This method, however, left little time for any in-class instruction and placed the onus for learning predominantly on the student. [Figure 3] [2] Due to the increase in the number of students compared to 1817 when the Thayer Method was first implemented, re-sectioning students by ability is no longer a viable option.
Finally, the authors included the Civil and Mechanical Engineering (CME) Department’s traditional pedagogy. In this model, the Thayer Method was modified over time to place fewer burdens on the students who were learning more complicated technical material. In this CME method, the students are expected to prepare for class by simply reading or skimming assigned portions of the textbook. The instructor provides an engaging lecture using physical models, laboratory exercises, demonstrations, and multimedia assets whenever possible. Time permitting, instructors or student groups work example problems in class. Instructors evaluate student performance using conventional instruments, most notably timed examinations. [2]

Over the past year, the authors developed and implemented an instructional method that employs blended classroom methods to improve student learning. Dubbed “Thayer 2.0,” [Figure 4], the method leverages technology and blends what the authors considered to be some of the best characteristics of the CME method, the original Thayer Method, and the Khan Academy. In conjunction with a literature review, a beta test of Thayer 2.0 was conducted for ten lessons during the spring semester of academic year 2013 (AY 13-2) to gauge student feedback and to establish operating procedures and instructional best-practices for a broader implementation. The lessons learned from that development and student input were discussed in a previous paper [2]. The question remained, however, if non-engineering students, some with no real interest in the subject matter, could be successful with a flipped classroom, self-teaching model. In the fall semester of academic year 2014 (AY 14-1), the fully implemented Thayer 2.0 pedagogy was employed for both sections of ME350 Introduction to Thermal-Fluid Systems with Army Applications, consisting of 36 non-engineering students. The results and observations of this study will be further explored in this paper.
Figure 4: Thayer 2.0 pedagogy relationships compared with the Thayer Method, the traditional method, and the Khan Academy Method.

Instructional Method:

Students were provided a syllabus, a text book, and a study guide complete with detailed lesson objectives, assigned readings, and practice problems. Lecture videos were posted on Blackboard by lesson objective. Most lessons consisted of three to five lesson objectives per lesson, as opposed to complete lectures. This method is similar to the concept of “teaching nuggets” proposed by Wallace and Weiner [4]. By making videos by lesson objectives, a course can be restructured without having to recreate entire lesson videos. Additionally, students can select objectives to watch or review without having to watch or skip through the entire lecture. Students were required to watch no more than 40 minutes of video footage prior to each class. Students were given a conceptual quiz at the start of a majority of the class periods valued at 10 points each for a total of 300 points or 15% of their overall class grade. The quizzes served to ensure that students would watch the videos prior to class. Additionally, the quiz results allowed the instructors to identify common areas of confusion, challenging concepts, and any deficiencies in how the videos presented the material.

In the classroom, students had the opportunity to witness live demonstrations and had access to training aids of concepts discussed in the videos. The students would also work study guide problems either individually on the chalkboards or at their desks like the Thayer Method. The instructors would move throughout the classroom and help students as needed to clarify issues similar to methods applied by Wallace and Weiner [4] as in-class exercises. At times, the students would work in pairs or teams as was done by Foertsch, et al. [5] as group projects. Additionally, if the instructor found that multiple students were struggling with the same part or whole of a problem, he would sometimes choose to demonstrate the problem on the board with the entire class as is done in the CME Method. These in-class exercises allowed students the chance to apply the concepts they had learned in their preparations prior to class (either from the videos or the reading) rather than to be lectured.
Students were also afforded time to work on homework in class while the instructor was available. (Based upon time estimated to complete homework, divided over the number of lessons from the date issued to due date). The intent was for students to work on homework problems in class so that the videos were not viewed as additional homework. [Figure 3]

Rather than provide a broad lecture, instructors were be able to tailor their instruction to the individual student via multiple means for multiple learning styles. They were able to explain specific topics based on an individual student’s comprehension of a lesson objective which allowed them to identify inaccuracies on-the-spot. In this manner, instructors were still be able to form genuine relationships with the students not as a “sage on a stage, but a guide on the side,” to use the words of Salman Khan.[6]

Desired Outcomes:

- Increase the time spent in the classroom solving problems. The goal was to increase a student’s ability to identify, formulate, and solve engineering problems. We hoped to increase one-on-one time in the classroom where the instructor could better approach each individual’s issue instead of providing a broad-spectrum lecture. USMA classes are limited to 20 students; which is about the maximum number of student one instructor could effectively split his/her focus. Larger course would require a teaching assistant or graduate assistant.

- Provide students with videos covering lesson objectives granting the student with the ability to pause, rewind, or re-watch as needed allowing them to learn at their own pace. Additionally the student is able to review the lecture after solving problems to improve his or her understanding of the material, ultimately, creating a valuable study tool for exam preparations. Ideally, the student would follow along with the textbook and take notes as well.

- Encourage and enable students to take more responsibility for their learning and become lifelong learners. Students need to understand the impact of engineering solutions in a global, economic, environmental, and societal context. As future professionals in a changing world they will be responsible to maintain a high level of knowledge and information with regards to their trade. The proposed approach will reinforce the concept that learning is not limited to the one hour spent in the classroom, but rather is refined while in the classroom. [1]

- Improve the quality and efficiency of student learning by conducting lectures outside of class and homework during class. We sought to level the time survey data [Figure 1] so that students performed as well or better as previous semesters with decreased time spikes and more consistent and predictable preparation. Decrease the intense amount of additional instruction (office hours) students seek for engineering courses which in turn reduces the required instructor preparation. This additional time will provide more time for instructors to focus on research and improving the next generation of engineers.
Performance Outcomes:

The most objective metric to evaluate the feasibility of the flipped classroom for non-engineering student is through traditional graded evaluations. However, evaluating student performance utilizing solely final course grades as a metric is difficult and uncertain given the multiple variables: different students from year to year, different homework and exams, and different graders for the assignments. What doesn’t change semester-to-semester is the final exam for the course, which is altered by no more than 10% each semester, solutions are never released to students, and the historic cut sheet is provided instead of being created by the grader. By using the final exam scores as the basis of comparison, variability was reduced though not eliminated. It did, however, provide us with a better assessment of whether or not the non-engineering students were able to solve thermal-fluids problems to the same level as previous students who learned the material using the CME method of instruction. If students performed similarly or better on the final exam, which encompasses the entirety of the course, one could draw the conclusion that non-engineering students can learn the material and develop an engineering problem solving methodology using the Thayer 2.0 method.

Below in Figure 5, the final exam scores are depicted for previous semesters of ME350.

By inspection, one can see that the students who completed the course using the Thayer 2.0 method performed on par with previous semesters taking the same exam. The mean final exam year from AY 10-1 to AY 13-2 was 87.43% with a standard deviation of 2.2%. Therefore, the AY 14-1 average of 86.06 was well within that range and is marginally higher than the year prior. The slight deviation below the average could be due to the individuals, due to the method, or most likely, due to slight variations in the graders’ interpretation of and adherence to the exam cut sheets. AY 13-2 is the best comparison because the course was taught by and the exams graded by the same instructors. Though the Thayer 2.0 method did not clearly result in a marked increase in student performance from the traditional method, it also did not result in a marked decrease which shows that the method in itself is successful with non-engineering students.
Outgoing Student Surveys:

In order to further evaluate the viability of the Thayer 2.0, the authors also chose to study student end-of-course survey data. While more subjective, it could be compared to data for the Academy, the department, the mechanical engineering program, and previous semesters of ME350. One of the primary goals of the Thayer 2.0 method was to encourage students to take responsibility for their own learning. It did not matter if students prepare for class by watching the videos, by reading the text, or a by a combination of both. What mattered was that students actually came to class prepared so that they could work problems and learn by doing not by lecture. It can be seen from Figure 6 below that on a standard Likert scale with one being “strongly disagree” and five being “strongly agree,” students taking the ME350 using Thayer 2.0 had a mean response of 4.75 with a standard deviation of 0.43 when asked if their “instructor encouraged students to be responsible for their own learning.” This value is 0.22 points higher than the remainder of the Mechanical Engineering Program (which includes the results of ME350), which had a mean of 4.53.

![Figure 6 AY14-1 "My instructor encouraged students to be responsible for their own learning"](image)

Furthermore, when asked if their critical thinking increased as a result of the course, students in the Thayer 2.0 method of ME350, AY14-1, responded with a mean of 4.31 and with a standard deviation of 0.91 (Figure 7). This response value is on par with both the Mechanical Engineering Program and the C&ME department, all of which are 0.1 higher than the mean response for the combined scores for all other courses in the cognitive domain at USMA.
One could arguably state that the positive response for ME350 is due solely to the content of the course and not the pedagogy used. However, it is important to note that the remainders of the courses in the department do not use the Thayer 2.0 methodology, yet the scores are the same. Additionally, when compared to data from AY 13-2 (Figure 8), the response increased by 0.1 for ME350 while the mean scores for the Mechanical Engineering Program and the department decreased by that same amount from AY13-2 to AY 14-1.

One of the greatest challenges of teaching non-engineering students in general is trying to get students who are taking a course outside of their chosen major to understand and appreciate the significance of the course. This concept was a significant concern for Thayer 2.0 since students would not be receiving a lecture and, therefore, would possibly have less opportunity for instructors to inspire the students and convey the importance of the material. For students who major in engineering, one would assume that this understanding should be self-evident. Therefore, it was surprising to find that when surveyed, the non-engineering students in ME350 undergoing the Thayer 2.0 method responded with a score of 4.5 of 5. This value was on par with the Mechanical Engineering Program with a similar standard deviation of 0.69, and only marginally lower than the department score of 4.57. (Figure 9).
"My instructor helped me to understand the importance and practical significance of this course."

Most encouraging was the fact that this response score increased by 0.3 from the ME350 students in AY13-2 while those for ME and the department decreased by 0.1 from the preceding semester (Figure 10). This data shows that with self-teaching, online videos, and in-class problem solving, most non-engineering students could be inspired to see the practical significance of the material.

Students also reported positively when asked about their confidence in their ability to apply their knowledge of mathematics, science, and engineering as a result of the course. (Figure 11) Their mean score of 4.44 was not only marginally higher than the Mechanical Engineering Program for AY14-1 but also showed a significant increase over ME350 from the previous year (Figure 12).

"This course improved my ability to apply my knowledge of mathematics, science, and engineering"

Recall the purpose behind the core-engineering sequence: the need for future leaders to be able to shape the physical world through their ability to identify, formulate, and solve engineering problems. When surveyed, students completing ME350 using Thayer 2.0 during AY14-1 showed a mean response of 4.42 (Figure 13), slightly higher than the Mechanical Engineering
Program, but remarkably 0.39 points higher than ME350 students in AY13-2 which used the CME Method. (Figure 14)

"This course improved my ability to apply to identify, formulate, and solve engineering problems"

However, not all student feedback regarding Thayer 2.0 showed positive results. One of the primary intended outcomes of the course was to increase students’ motivation to learn and to become lifelong learners. The survey results (Figure 15) indicated a mediocre response (3.81 with a large standard deviation of 1.22). This response was well below the averages for the Academy, the department, the program, and the previous year for the same course. (Figure 16)

Figure 15 AY 14-1 “My motivation to learn and to continue learning has increased because of this course.”
Thayer 2.0 resulted in non-engineering students who are more confident in their abilities to solve engineering problems but less motivated to learn any more about them. One of the key assumptions of self-based learning models is that students’ will be interested in the material. However, for some the course became too much work and too little fun; it could also simply be a reflection of the students’ bias or disinterest in engineering to begin with. Without a requirement to complete the course, it is unlikely that students would choose to learn the course topic on their own. Like any class, there is a broad range of students. When teaching non-engineering students, students’ attitudes ranged from thinly veiled disdain for engineering by those who saw the course as an unnecessary and overly difficult burden, to students within the course who would send the instructors articles, web links, and videos of related topics beyond those that were taught in the course. It is unlikely that this interest gap will ever be eliminated but it is clear that a lecture based model seems to be more effective in reducing it. A video lecture must state the facts as concisely as possible in the interest of time. A good video lecture includes the instructor’s introspection and should be enthusiastic. However, there is only so much genuine enthusiasm that can be relayed in recorded format. Without interaction, student questions, and classroom dialogue, it is difficult to inspire the uninterested to want to learn more; particularly when the material is not in their chosen field of study. Many times, those inspirational moments come from a student inquiry or comment in class that the instructor did not plan or think of. That is not to say that video lectures and class room problem solving create an unnatural separation between the teacher and the student. Nor do the video lectures create a teacher who simply stands at the side, seemingly unnecessary, as critics of flipped-classrooms may claim.

Student-Teacher Relations:

Creating lesson objective videos is a difficult and time consuming venture as was discussed our previous paper [2]. However, if done correctly, combined with various methods for in-class problem solving, the technique can be as effective as traditional methods for teaching. Figure 17 (below) illustrates student responses when asked if the instructor used effective techniques for learning, both in class and for out-of-class assignments. For the Thayer 2.0 ME350 course, the students responded with a nearly identical mean score and standard deviation as the remainder of the Academy, courses within the cognitive domain, the department,
and the Mechanical Engineering division with a higher minimum value with a smaller sample population.

![Figure 17 AY14-1](image1)

"This instructor used effective techniques for learning, both in class and for out-of-class assignments"

More notably, the mean score for Thayer 2.0 method of ME350 increased by 0.24 from the previous semester that utilized the standard CME method. (Figure 18) One might note, however, that the standard deviation is greater for the Thayer 2.0 method (Figure 17&18) and has a lower minimum than for the previous year. This larger disparity will be discussed further later in the paper.

![Figure 18 AY13-2](image2)

"This instructor used effective techniques for learning, both in class and for out-of-class assignments"

One of the keys to the effective techniques lied not only in the production of the videos but in the problem solving in class. When originally conceived, Thayer 2.0 was going to require students to work all problems on their own either at the boards or at their desks. While this methodology is likely to be successful with engineering majors, the authors found that it was not always effective with non-engineering majors. For many of the non-engineering majors, it had been more than a year since their last physics, engineering, or mathematics courses. As one might expect, these students struggled with in-class problem solving to a point that some did not even know how or where to start a problem. On the other hand, the students who were physics or
chemistry majors were solving problems quickly. Every class has a dynamic and a collective personality, this aspect is no different with a flipped classroom. The instructors decided to adapt the in-class problem solving relative to the material, the students’ perceived understanding of that material based upon the daily quiz scores, and the frequency of the exposure to the material. If the topic were new or more difficult, the instructor would demonstrate the problem on the board with interaction and input from the class. If the problems were fundamental or the students had completed similar problems previously, the students completed to problems at the boards. However, student dialogue and interaction was authorized; this technique allowed the instructors to leverage the students who were understood the material. By doing this, it reinforced the material to the student providing help, increased the efficiency of the instructor by allowing more students to receive help, and provided struggling students with a different presentation or approach of the material by a peer. Following board work, students would be selected by the instructor to brief the class on how they solved the problem. This traditional Thayer Method technique helps to ensure that struggling students would not just copy someone else’s board because they would have to explain it. As an instructor it was important to continually monitor the students’ work on the boards to identify where each student was struggling and where multiple students were struggling. This way, the instructor could help an individual or help guide the entire class back on azimuth. Additionally, during the briefings by the students, it was beneficial to direct students’ attention to multiple boards as a means to show and explain different techniques and paths to solve the same problems. This allowed students to see more correct methods than a singular one demonstrated by the instructors. Finally, if students were working homework, it was done individually at their desks, usually with classical music playing at a low volume to provide a more relaxing, less exam-like atmosphere.

By adapting in-class methods, the instructors were able to stimulate the students’ thinking equally as well as traditionally instructed courses within the Academy, domain, department, and mechanical engineering program, (Figure 19) with a moderate improvement from the purely lecture-based ME350 of the year prior (Figure 20).

Additionally, these personal interactions with the students whilst solving problems were as effective as traditional methods at demonstrating the instructor’s concern for student learning (Figure 21).
Lastly, students’ were able to identify the time and effort the instructors put into the creation of the lecture videos. When lecturing, everyone makes mistakes, some of which the students identify, some of which the instructor self-identifies either during or following a lecture. Such mistakes are natural and actually help to increase student interaction and help to humanize the instructor. However, such is not the case with a lecture video. Attention to detail and accuracy are important. There are no students to stop you at the boards and ask a question; there are no alibis. What you put on video is eternal. The students will learn the material using solely these videos and their textbook. The entire purpose of making your own lesson objective videos is to provide students with course specific and correct/accurate information regarding the topic. This fact is a cause for a lot of research prior to the creation of videos, fact checking, and, often times, editing and reshooting. All of these are time consuming. As a result, however, students responded extremely positively when asked if their instructors (the creators of the videos) demonstrated depth of knowledge in the subject matter. ME350 Thayer 2.0 scored a 4.94 of 5.0 with a standard deviation of only 0.23 and a minimum score of 4.0—a full 0.3 points greater than the Mechanical Engineering program and 0.21 points higher than the department. It can, therefore, be concluded that it is important for developers of flipped classrooms to create their own videos. (Figure 22)
One of the additional goals of the Thayer 2.0 method was to level the time survey data [Figure 1] so that students perform as well or better as previous semesters with decreased time spikes and more consistent and predictable preparation. It was understood that regardless of the methodology used, spikes would always occur before exams when students increase study and prior to the submission of lab reports and projects for which students were not afforded class time. However, the authors hoped that, with Thayer 2.0, homework spikes would be eliminated. Unfortunately, this method was unable to eliminate spikes in time spent outside of the classroom for homework; despite the fact that it allotted classroom time for homework completion. (Figure 23) In some cases, students did not make the use of the time afforded, in others, the instructors failed to estimate the time it would take the students to complete assignments or failed to afford enough time. There were several lessons where time for homework was reduced because it took too long for the class to solve a problem or because so many people performed poorly on the daily quiz that the first twenty minutes of class were spent clarifying topics that some students had struggled with from the videos.

However, by comparing time survey data from AY14-1 to AY13-2 (Figure 24), some positive comparisons can be made in support of the Thayer 2.0 method. While the flipped classroom did not eliminate spikes, it did successfully reduce the magnitude of a majority of the peaks, while simultaneously reducing the cumulative average outside the classroom and increasing the daily preparation time for each class. AY 13-2 demonstrates multiple lessons with a preparation average of less than five minutes.
Obviously the increased daily preparation is a direct reflection of the requirement to watch video lectures prior to the class, but is shows that students are actually doing it. It is imperative that the students watched the videos prior to class, lest they would not understand nor have been able to solve problems--effectively making class periods worthless. The authors chose to ensure compliance through daily quizzes at the beginning of class. These quizzes were administered on
a traditional paper format, consisted of purely conceptual questions based directly from the lesson objectives and were limited to five or ten minutes. The instructor then reviewed the quiz with the class and allowed students to self-grade. The quizzes were then passed in and problem solving initiated. When asked for free text comments about the course and the Thayer 2.0 method, students opinions on the course were nearly equally split, though supporters of the method were passionately so. What was consistent amongst students nearly across the board, however, was their collective dislike of the daily quizzes. Many simply stated they did not like the daily quizzes but did not elaborate. Other students offered that the quizzes should have been offered with less frequency because they cut into class time that could have otherwise been used to solve problems and work on homework. While these students are correct about cutting into class time, the authors do not believe that eliminating the quizzes is an option. Even with daily quizzes some students came to class unprepared at times and could not follow along with the problems or when they were working individually would monopolize the instructor’s attention.

There must be some form of enforcement for daily preparation. The authors propose three options to address this problem. The course could be completely self-paced with computer based problems completed individually in class as done by Capaldi in his STEMSI Online Learning Environment [9]. Such a method, while ideal, requires the creation of an online learning environment and authorization of the institution to allow a truly self-paced course, neither of which the authors have.

A second alternative would be to post daily quizzes to some online medium such as Blackboard for students to complete prior to class. This method has two benefits. First, class time would not be spent on quizzes, freeing up between 10-20 minutes per lesson; a significant increase over forty lessons (between a 122% and 157% more usable class time). It would also allow the instructor to view student scores prior to class for a better idea of where students are struggling. This method is not without its drawbacks. Most obviously, there is no way to ensure that students do not simply obtain the answers from a friend. While this is ethically objectionable, it also does nothing to ensure that the students come prepared to effectively utilize class time.

A third alternative, likely to be adopted by the authors, is to use a feedback response program such as iClicker to allow students to take the quiz quickly, have responses automatically graded so that the instructor can immediately identify trends, and allow students to immediately begin working problems upon completion so as that they are not held back by those struggling on the quiz.

Conclusion:

While teaching non-engineers may seem like an educational scenario that is specific to this institution, it is likely to become more common place due to the STEM initiative philosophy outlined by President Barack Obama when he stated that “Leadership tomorrow depends on how we educate our students today—especially in science, technology, engineering and math.” [8] It behooves students of all levels of higher education to have some type of STEM background in their curriculum, since many of the major issues the nation will face in the future (energy, environmental, infrastructure, etc) will “require the technical expertise and savvy problem solving of the engineering mind.”[9] While this experiment was used in a mechanical engineering course, it can just as easily be applied to any STEM discipline course.
For these non-engineering students, we conclude that flipped classrooms are a viable option when compared to traditional lecture based methods of instruction. All-in-all, non-engineers increased their knowledge of engineering and their confidence in their ability to formulate and solve engineering problems. However, this method required significant increase in the individual effort of the students, making them more responsible for their own learning but less motivated to continue to do so in the future. What must be considered is the desired outcome. Is it more important for the non-engineers to learn the required concepts and be able to apply them while learning how teach themselves the material while in a course? Or is it more important to motivate them to learn more engineering on their own? We would argue the former is more important. Not every non-engineering student will be interested in engineering, just like many engineers find other academic topics uninteresting. What is important is that these non-engineers have developed the tools to learn what they must when the time arrives that they may need it. It is our belief that a flipped classroom with problem solving helps reinforce their ability to do just that.

References:


