122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #12337

A flipped course in modern energy systems: preparation, delivery, and post-mortem

Dr. Matthew Turner, Purdue University (Statewide Technology)

Dr. Matthew Turner is an Assistant Professor of ECET at Purdue University New Albany where he teaches courses in power systems and controls. Prior to joining the faculty at Purdue, Professor Turner worked as a researcher at the Conn Center for Renewable Energy Research in the area of power and energy systems, with a focus on smart grid implementation and computer modeling. Dr. Turner's current research concentrates on demand response technologies and the application of novel teaching and learning methods to power engineering education.

A flipped course in modern energy systems: preparation, delivery, and post-mortem

Abstract

In the flipped classroom model, students are assigned to read material or view videos on class topics before coming to class. The traditional lecture period can then be used to engage students via a variety of methods including active learning techniques such as peer instruction, labs, and problem sets. Cited advantages of this pedagogical method include, amongst others: time to spend with student on authentic research, time to work with scientific equipment in classrooms lecture content can be viewed repeatedly, the method promotes thinking both inside and outside of the classroom, and students are more actively involved in the learning process. All of these advantages share a common philosophy; online instruction can be used at home to free class time for learning.

This paper presents the implementation, delivery, and analysis of a flipped course in electrical power engineering technology at the undergraduate level. The methods used are characterized in terms of existing evidence based research for practical and effective instruction, and instructor and student feedback is included for comparison. First, a method of converting the traditional lecture based instructional content into web-based videos using a low-cost do-it-yourself smart board is presented, as well as the organization of video content into online playlists for ease of viewing. Second, methods of monitoring student completion of out-of-class assignments are evaluated, and the use of low-stakes online quizzes is presented as such a tool. The restructuring of class time is then discussed, including the use of deep learning activities, problem based learning, peer instruction, laboratory based learning, and traditional problem sets. The paper is concluded with a summary of reports on student's perceptions of the flipped methodology. Throughout the paper, both the benefits and the pitfalls of the flipped classroom method are highlighted, and the importance of proper instructional design is emphasized.

1. Introduction

The basic premise of the flipped class room instructional method, often called the inverted classroom, is that online instruction at home frees class time for learning. In this pedagogical model, asynchronously delivered online video lectures take the place of direct-live instruction. Custom videos can be created by the course instructor or can be chosen from the increasingly large inventory of online content, such as those provided via Kahn Academy[1]. Class time previously reserved for "chalk and talk" lectures is instead spent directly interacting with students, performing activities that are not easily computer automated, such as practice exercises and problem solving. Therefore in a flipped classroom, activities that historically have been performed in class are performed at home and vice versa, i.e. a re-ordering of the traditional class structure.

It is increasingly becoming evident that a more specific definition of the flipped classroom is necessary, as instead of merely a re-ordering, the successful flipped course actually expands beyond the typical course curriculum by including activities based on proven active learning methods focused on knowledge integration and application[2]. In their review of flipped classroom research, Bishop and Verleger[3] propose a re-definition that includes two parts:

interactive group learning activities inside the classroom and direct computer-based individual instruction outside the classroom, as shown in Table 1.

Table 1: Traditional and active definition of the flipped classroom, adapted from [3].

Style	*Inside of Class*	*Outside of Class*
Traditional Flipped	• Lectures • Practice Exercises • Problem Solving	• Practice Exercises and Problem Solving • Video Lectures
Active Flipped	• Question and Answers • Group-Based and Open Ended Problem Solving	• Video Lectures • Closed-Ended Quizzes & Practice Exercises

The educational approach described in Table 1 is seeing increasing utilization amongst engineering and technology educators because when properly implemented, the active flipped course method enables instructors to implement active learning methods without sacrificing course content [4]. In the traditional classroom, tools such as collaborative learning, cooperative learning, and problem-based learning [5-7] can be difficult to implement within the 50 to 80 minutes traditionally allotted per instructional period. Often, the lecture time lost when implementing such methods results in a decrease in the amount of material covered in a semester course, and a flipped course provides instructors with the opportunity to re-capture this time[8], and has proved successful as either a complete flip or when implemented more selectively, such as when only a portion of the material is transformed[9].

Despite the increasing body of evidence supporting flipped classrooms, many engineering and technology instructors do not feel comfortable implementing the flipped classroom, primarily related to (1) having high comfort level with traditional lectures, (2) insufficient time to develop flipped materials, and (3) unfamiliarity with the actual process of flipping a course. The purpose of this paper is to these address issues by presenting the process utilized to transform a recently flipped course in Purdue University's School of Engineering Technology, review the methods by which the course content was delivered, and to present student responses to the instructional methods utilized.

2. Course Framework

ECET 27300 Modern Energy Systems is an introduction to energy system technologies course taught to 1st semester sophomores pursuing a B.S. degree in Electrical Engineering Technology. The primary instructor's anecdotal observations of the course were that the majority of students were surface-learners; tending to memorize facts and reproducing problems through rote memorization, instead of deep learners who focus on understanding the meaning of the material and the integration of new concepts with their knowledge of the world[10]. To address this issue, a course re-design was performed through participation in the Purdue IMPACT program with the goals of increasing student engagement, competence, and attainment of course learning outcomes by implementing the research-based pedagogies of collaborative learning, in which students work together in small groups to answer questions, and problem-based learning, where relevant problems are introduced prior to the instruction cycle and used to provide context and motivation. An additional important consideration of the course re-design was to preserve the hands-on engineering component of the course in which students participate in extensive laboratory activities. As such, the active-flipped method was chosen. In this way, the benefits of direct instruction through "chalk and talk" are mostly preserved, with the added benefits that students can repeat video content as necessary. Additionally, by flipping the class room, in-class time can be reappointed for multiple active learning strategies.

The above course-design strategy was implemented in a closed-loop system as presented in Figure 1. This implementation was divided into three areas of instruction: pre-class activities, in-class activities, and post-class activities.

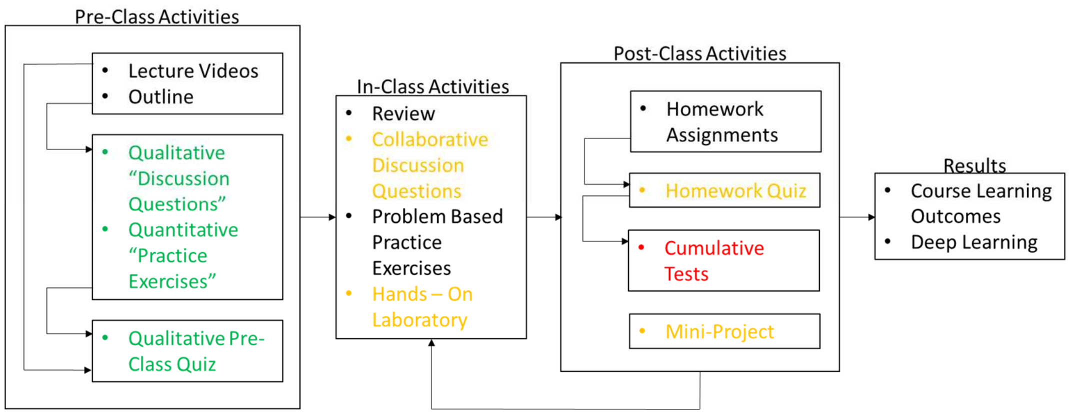

Figure 1. Closed-loop course structure.

The length of the following activity "module" would typically be implemented across two 1 hour 50 minute class meetings. In order to maintain 540 minutes or fewer of activities (3 credit hours), the homework content of the class was reduced by approximately 90 minutes per module, as this content is covered in the class session.

1) Pre-Class Activities: Utilizing the flipped model, students were assigned a video lecture for study prior to attending each class. The video lectures were accompanied by a handout/outline and two worksheets: a list of qualitative discussion questions and a set of unsolved quantitative practice exercises. Students were instructed to review the lecture handouts, discussion questions, and practice exercises prior to viewing the video lectures. Upon completion of the video, students were required to take a short pre-class online multiple choice quiz. The quiz questions were designed to assess at the knowledge and comprehension levels of Bloom's taxonomy[11], and served as a low-stakes assessment to encourage completion of the video. Additionally, students were asked to begin formulating responses to the discussion questions and practice exercise. Students work was later evaluated for completion/participation, but not accuracy.
2) In-Class Activities: The first 30 minutes of each class session were reserved for a high-level review of the video lecture and was followed by a review of the online quiz. The statistical data collected from the online pre-class quiz provided a tool by which the instructor could focus the limited available review time, however reviews were structured to be informal discussions, presenting students with the opportunity to ask questions and clarify concepts. After the review, approximately 55-minutes of class were used for peer instruction in which

groups of two or three students formulated a single group answer to the list of discussion questions. Groups were then randomly called upon to provide a unified answer to a single question, which was graded by the instructor. Other groups were provided the opportunity to "steal" the questions by providing more complete answers, which was rewarded with bonus credit for the day's evaluation. Feedback was then provided by the instructor to clarify any misunderstandings. Approximately 55-minutes of class were then used to solve the practice exercises as a group, with the instructor acting as a guide, but with the students performing all analysis and mathematical calculations. A hands on laboratory activity related to the in-class content then was performed, typically lasting 60 to 75 minutes.

3) Post-Class Activities: After several modules were completed, homework problems were assigned, encouraging individual problems solving, with solutions provided to the students to perform self-assessment. A post-class quantitative quiz was then given during class time as a medium-stakes assessment of learning designed to assess at the applying and analyzing levels of Bloom's Taxonomy. At the midterm and final of the course comprehensive tests were given as high stakes assessments. In order to deepen the connection of the class to real world applications, several mini-projects were assigned throughout the semester. A complete description of the projects is outside the scope of this paper, but some examples include a poster linking energy consumption to quality of life metrics, a biographical paper on an important figure in the early electrification of the United States, and a presentation on demand reduction techniques suitable for implementation at an electric cooperative.

Throughout the closed-loop course structure feedback was provided to the students via low (green), medium (yellow), and high (red) stakes assessments, as depicted in Figure 1. In this methodology, a low-stakes assessment is assigned when students have had minimal exposure to a course topic and have not had the opportunity for feedback. Such assessments are frequent and formative, intended to give the student immediate feedback regarding how the student is meeting the most basic of class expectations, and are weighted to have minimal impact on the student's final grade. Medium stakes assessments are delivered less frequently, after a student has had time to prepare are clarify with the instructor and have a larger impact on the final grade. High stakes assessments are summative, the most infrequent, and in this implementation consisted of a mid-term and final exam.

Table 2 summarizes the relative weights given to the different assessment methods utilized throughout the course. Although receiving equal weight towards the final grade as the mid-term and final, the laboratory instruction is considered a medium states assessment due to the large number of individual assignments.

Table 2. Weighting of high, medium, and low stakes assessments towards final course grade.

Assessment Category	*Percent Final Grade*
Online Quiz	5%
Discussion Question/Practice Exercise Participation	5%
Group Discussions	10%
Homework Quiz	10%

Labs	20%
Mini-Projects	10%
Mid Term	20%
Final Exam	20%

3. A Practical Method for Course Flipping

Converting a traditional lecture course for delivery via the flipped method consists of the following elements: creating and host the video content, creating and implementing a gating activity, creating in-class learning activities, and creating post-class assessment and review activities. Much of the content required for a flipped course can be-repurposed from a traditional course, and therefore the creation and production of the video content likely will be the most time consuming element.

Video Content: The purpose of the video lectures is to allow students to acquire course content in advance of the class meeting, i.e. to gain a first exposure. The mechanism to achieve this can be as simple as a reading assignment, or more elaborate such as a video recording, with most successful flipped models implementing this approach[3]. When implementing a video strategy, either a curate or create method can be employed. Curated content is that which materials are borrowed or purchased, but not created, by the course instructor. Sources of curated content are typically found online and can include YouTube lectures from other universities, the library of congress media library, and MIT opencourseware amongst others. In contrast, created content is original media created by the course instructor. This can be the use of lecture capture tools such as Tegrity to record live lectures for re-use in a flipped classroom in a subsequent semester, creating a narrated power point video with screen capture tools such as Jing or Camtasia, or the creation of fully custom lecture videos.

In flipping Modern Energy Systems fully-custom lecture videos were created based on Power Point presentations previously developed for the course. In order to preserve the traditional blackboard “chalk and talk” feel of a course, a low-cost and portable video recording studio (Figure 2) was developed based around the Wiimote Whiteboard[14], a free-ware tool that converts any flat screen surface into an interactive digital whiteboard. To build the whiteboard, a 4x8 sheet of low density polyethylene (LPDE) was attached to a frame constructed of 2x4s. A projector and Nintendo Wiimote were then placed behind the whiteboard screen, with the projector configure to operate in the rear projection mode. A PC projected a computer desktop onto the digital whiteboard, which could then be manipulated using either a wireless presentation remote or an IR pen which allowed for freehand drawing. After evaluating several software tools for presentation purposes, the freeware graphic editor/viewer Infranview[15] was chosen due to the large set of useful presentation features available. To record the lecture, an HD video camera was placed in front of the digital-whiteboard and screen capture software was run on the PC, resulting in two concurrent videos. Additionally, a wireless microphone was used to produce quality audio. This arrangement provided some advantages as compared to other video creation methods:

- Normally when interacting with a PowerPoint presentation, the presenter will cast a shadow when in between the whiteboard and projector. The use of the digital whiteboard allowed for the instructor to interact with digital content without obstructing the student view, similar to the use of a tablet PC or laptop.

- Having a two video stream enabled the students to see gestural information (e.g. pointing) that would be lost in a “talking head” or tablet method.

After recording the screen capture of the computer desktop and the live video of the instructor, the two separate video files were combined together using Adobe Premiere, resulting in a single video presentation, as seen in Figure 2.

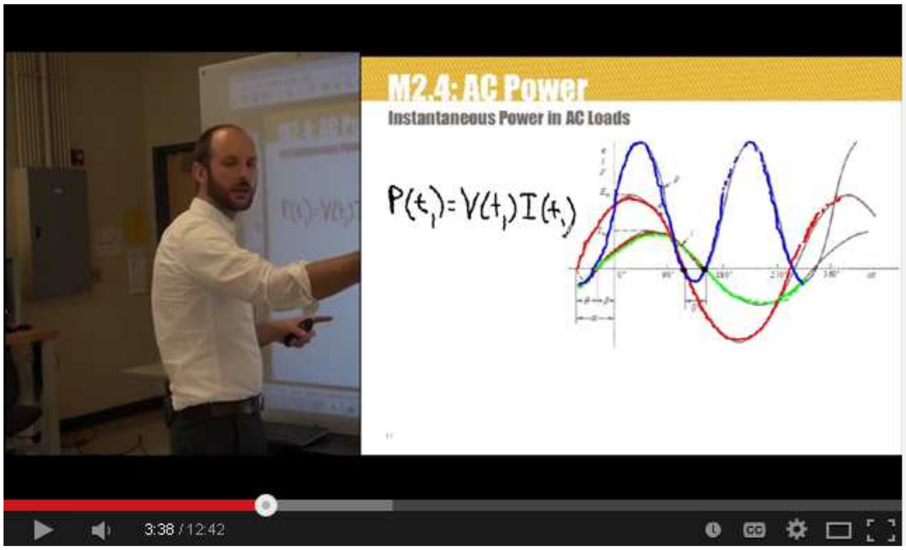

Figure 2. Digital whiteboard and screen capture video composite.

Video Hosting: The final edited videos were published in the MP4 format which is suitable for most internet hosting sites and most personal digital media players. The videos were then uploaded to a YouTube channel created for the course and arranged into playlists to manage and link related video content to play in a pre-determined order. The course playlists can be viewed at:

https://www.youtube.com/channel/UCVJmHDgDo9nraTDgFvHMHjA/playlists

By having students subscribe to the YouTube channel they were automatically notified when new content was uploaded. Additionally, the course videos were distributed in digital file-format using the university’s server storage allocated for the class. Hosting the media in multiply accessible formats was important as not all students had access to high speed internet for video streaming. Other common video distribution options include Canvas or Blackboard.

Gating Activities: Gating activities are mechanisms that provide an incentive for students to prepare for class that can also be used to assess student understanding of the video lectures and to provide immediate feedback. Ten question multiple choice online quizzes were developed for each video lecture and were deployed in Blackboard, with much of the material coming directly from previous semester’s assessments. To prevent cheating, quizzes were auto-generated from large question pools, with both order of questions and order of the options randomized for each quiz. The use of multiple choice was selected as they can be auto-graded, with individualized feedback given to students and summative reports generated for the instructor. Individual reports can help students identify areas of weakness or misunderstanding to work on before class, and summative data can aid the instructor in tailoring class-room activities to focus on areas of documented difficulty.

In Class Activities: To fully benefit from the flipped class pedagogy, the video lecture content must be linked to active learning techniques applied in the classroom setting under the supervision of the instructor, and ideally these activities focus on high level cognitive techniques. Common strategies include think-pair-share, polling, guiding questions, discussion, media analysis, collaborative learning, and problem-based learning. The discussion questions used in Modern Energy Systems were taken from end-of chapter summaries in text books and from previous semester assessments. The practice exercises were taken from end-of chapter problems sets and were also developed by the instructor. The important change at this stage of flipping is not in the content, but rather in the interaction of the student and instructor with the content, in this case the utilization of peer instruction where students teach each other by explaining concepts and defending answers, and group problem solving which involves students working together to solve a problem with the instructor providing structure or guidance when necessary.

Post-Class Assessment: With the exceptions previously mentioned, the same assessment methods utilized in traditional course structures are useful in the flipped classroom. If using active learning activities for assessment, having a rubric can help to articulate expected outcomes. In the Modern Energy Systems flip, the same homework quizzes, midterm and final were used as in previous semester, and grading rubrics were developed for each of the collaborative discussion question exercise.

4. Results

To assess the flipped course an end of semester survey was distributed and completed by 88% of students, with n=7. Overall, the student response was negative to the pre-class instructional videos, as shown in Table 3. From the open ended responses, students found the videos to be overwhelming, particularly the inability to stop the instructor and ask clarifying questions. Similar results have been reported in other flipped classroom studies involving early career students, suggesting freshman and sophomore students may not yet have developed the appropriate study skills to independently utilize flipped content[8]. This conclusion is further supported by the low number of students who reported utilizing the video content in a closed-loop fashion to address identified weaknesses and that 86% of students reported watching the playlists in a single session and not in shorter segments. This was particularly surprising given that the average playlist length was 1 hour 30 minutes while the average video clip length was under 20 minutes. In contrast, the majority of students reported that the post-video quizzes helped them better understand course material, adding further evidence to the case for frequent, low stakes, formative feedback. When asked their opinion on how to best utilize the video content, 100% of students suggested utilizing the video as ancillary/supplemental content and to revert back to traditional live-lecture.

Table 3. Student Response to Pre-Class Activities

	Strongly Agree	*Agree*	*Neither*	*Disagree*	*Strongly Disagree*

The video lecture aided my understanding of the course material.	0	1	1	2	3
I prefer video lecture to live lecture.	0	0	0	3	4
I often re-watched videos to better learn course concepts.	0	2	1	3	1
The online quizzes aided my understanding of the course material.	0	4	1	0	2
I was motivated to watch the videos because of the graded online quiz.	4	3	0	0	0

Student response to the active learning strategy of peer discussion implemented in place of traditional lecture instruction was more positive, as demonstrated in Table 4. Open ended responses indicated that the students enjoyed the interactivity and critical thinking required of solving the discussion questions and being exposed to the thinking behind their peers' solution methods. However some students felt a sense of frustration when the answer to the discussion question wasn't directly provided in the on-line videos. Many students reported anxiety at being asked to answer questions in front of their peers and frustration in having to listen to incorrect responses. Several suggested that the class be given time to work on them in teams, but that the instructor provide the answers during the review period.

Table 4 Student Response to In-Class Activities: Discussion Questions

	Strongly Agree	*Agree*	*Neither*	*Disagree*	*Strongly Disagree*
The discussion questions aided my understanding of the course material.	1	5	0	0	1
Having the discussion questions in advance helped me to better utilize the video lectures.	2	4	1	0	0
Working with a partner to answer discussion questions aided my understanding of the course material.	1	5	0	0	1
Answering discussion questions in front of class aided my understanding of the course material.	1	1	1	2	2
Hearing other groups' answers to discussion questions aided my understanding of the course material.	1	3	0	0	3
I prefer the use of discussion questions as compared to live-lecture.	0	2	2	1	2

I would recommend that this course continue to use discussion questions as an instructional tool.	1	3	1	1	1

Of the instructional techniques implements, group solving of the practice exercises was the most highly evaluated by the students. Table 5 summarized student responses. Open ended feedback revealed this enthusiasm to largely be driven by the perceived correlation between practice exercise problems and the questions appearing on the mid-term and final exams.

Table 5 Student Response to In-Class Activities: Practice Exercises

	Strongly Agree	*Agree*	*Neither*	*Disagree*	*Strongly Disagree*
The practice exercise aided my understanding of the course material.	0	4	2	0	1
Having the practice exercises in advance helped me to better utilize the video lectures.	1	4	3	0	0
Working on practice exercise before class aided my understanding of the course material.	0	5	2	0	0
Answering discussion questions in a group setting aided my understanding of the course material.	6	1	0	0	0
I prefer the use of practice exercises as compared to live-lecture.	0	3	1	2	1
I would recommend that this course continue to use practice exercises as an instructional tool.	0	4	2	0	1

In the assessment of Post-Class activities (Table 6), homework was identified as the most effective, with homework quizzes scoring similarly. Interestingly, open ended comments revealed a strong divide on the subject of the mini-projects, with approximately half of the students expressing enthusiasm for the projects ability to link class-work with real world problems and the 2^{nd} half feeling them to be a waste of time.

Table 6 Student Response to Post-Class Activities

	Strongly Agree	*Agree*	*Neither*	*Disagree*	*Strongly Disagree*
The homework aided my understanding of the course material	1	6	0	0	0

The homework quizzes aided my understanding of the course material	0	6	1	0	0
The projects aided my understanding of the course material	0	3	2	2	0
The mid-term and final aided my understanding of the course material	1	2	3	1	1

5. Conclusion

The primary motivation to flip a classroom is to improve student learning by increasing the students' engagement with the course material, primarily be re-arranging lecture time to facilitate active learning strategies that would otherwise be too time consuming to implement in a lecture. Although flipping introduces increased flexibility into otherwise crowded 50-minute lectures, flipping should not be viewed as a method to add a significant amount of additional topics to a course, although it does enhance the ability to discuss engineering applications and place course content in a real world context.

Once a course has been chosen for flipping, a change in thinking must occur in both the instructor and the students. Instructors must carefully evaluate their course learning outcomes and make sure that lecture material, learning activities, labs, and assessments work together in a closed loop system, with multiple types of feedback to the students integrated throughout. This change in paradigm, coupled with the increased workload of creating lecture videos, is time consuming to prepare and can result in course preparation times several times longer than for traditional lectures. Additionally, the course instructor must become comfortable with what can often feel like a very chaotic learning environment

Regarding students, the approach implemented was not overwhelmingly viewed as positive. Many are used to "chalk and talk" lectures and find active learning uncomfortable. Having to take responsibility for their own learning experience can feel like additional work, and "aren't they paying for the instructor to do that?" Therefore, students who have not been appropriately scaffolded prior to the course flip may-not "know how to learn", and this is a required skill in a flipped course. Although anecdotal, an implementation of the flipped method by the same instructor in a 2^{nd} semester junior level course has been met which greater enthusiasm by the students. This contrast in in flipping higher level and introductory courses suggest that it is better applied to junior and senior level courses. However, it should be noted that the sample size of this work is from seven respondents, which is a major limitation of the findings.

Once implemented, flipping is not a panacea for the traditional passive learning environment. Although many students were actively engaged, the implementation of the flipped classroom chosen for Modern Energy Systems essentially made it impossible for students who had not done the preparation work in advance to participate in class, and thus they lost out on the prior instruction and the active learning. Additionally, the approach seemed to work well with outgoing students, while more introverted students clearly struggled with the required interpersonal interactions. Although the implemented gating strategy was successful in motivating the majority of students to prepare for class, almost universally students felt it was unfair that they be graded on the discussion questions, as they were not given sufficient time to review information provided in the short in-class reviews. This was despite the low-stakes assessment mechanism, suggesting students have a real difficulty getting past the "points system" that is ingrained by many high schools.

This implementation was the instructors 1st experiment with flipping, so the results are biased by inexperience with the method, as well as the previously mentioned limitations. Ultimately, the experience proved to be an exciting way to teach, and whether students indicated it via survey or not, they were definitely more engaged in class than previous semesters, and the method holds promise for having significant positive impacts on student learning if properly implemented. However more effort is needed to match the techniques used to the comfort level and capabilities of the students, particularly the total replacement of traditional lecture with video lecture which may have been more successful if a hybrid approach had been utilized.

6. References

[1]. https://www.khanacademy.org/ (accessed January 2015)

[2]. C.C. Bonwell and J.A. Eison, *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports*. ERIC Clearinghouse on Higher Education, Washington, 1991.

[3]. J.L. Bishop and M.A. Verleger, "The flipped classroom: A survey of the research." *ASEE National Conference Proceedings,* Atlanta, *GA*. 2013.

[4]. G.S. Mason, T.R. Shuman, and K.E. Cook, "Comparing the effectiveness of an inverted classroom to a traditional classroom in an upper-division engineering course." *Education, IEEE Transactions on,* vol. 56, No4, 2013.

[5]. M. Prince, "Does active learning work? A review of the research." *Journal of engineering education*, vol. *93 no.* 3 M. 2004.

[6]. R.M. Felder, "The future of engineering education II. Teaching methods that work." *Chemical Engineering Education*, vol. 34, no. 1, 2000.

[7]. S. Zappe et al., "Flipping" the classroom to explore active learning in a large undergraduate course." *ASEE National Conference Proceedings*, Austin, TX. 2009.

[8]. M. Cavalli, "Comparison of Student Performance and Perceptions across Multiple Course Delivery Modes." *ASEE National Conference Proceedings*, Indianapolis, IN. 2014.

[9]. T. Swift et al, "A Partial Flip, a Whole Transformation: Redesigning Sophomore Circuits." *ASEE National Conference Proceedings*, Indianapolis, IN. 2014.

[10]. C. Chin and D.E. Brown, "Learning in science: A comparison of deep and surface approaches." *Journal of research in science teaching, vol.* 37 no. 2, 2000.

[11]. L.W. Anderson et al, *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, abridged edition*. Longman, White Plains, N, 2001.

[12]. J.S. Cole and S.J. Osterlind, "Investigating differences between low-and high-stakes test performance on a general education exam." *The Journal of General Education,* vol. 57, no.2, 2008.

[13]. A.R. Napoli and L.A. Raymond. "How reliable are our assessment data?: a comparison of the reliability of data produced in graded and un-graded conditions." *Research in Higher Education*, vol. 45, no. 8, 2004.

[14]. http://www.wiimoteproject.com/wiimote-whiteboard/low-cost-multi-point-interactive-whiteboards-using-the-wiimote/

[15]. http://www.irfanview.com/ (accessed January 2015)