ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

2017 Pacific Southwest Section
Meeting: Tempe, Arizona Apr 20 Paper ID #20713

Lecture Videos to Supplement Electromagnetic Classes at Cal Poly San Luis Obispo

Dr. Dean Arakaki, Cal Poly State University

Dean Arakaki is an Associate Professor in the EE department at Cal Poly San Luis Obispo. He teaches courses in electromagnetics, RF systems, wireless communications, and antennas. He received the Ph.D. in electrical engineering in 2000 from Penn State University, University Park, PA. His current interdepartmental projects include algae biofuel and neutrino detection projects with biology and physics students and faculty. He is interested in developing methods (e.g. the inverted classroom) to enhance the learning experience for EE students.

Lecture Videos for Electromagnetics Classes at Cal Poly San Luis Obispo

Abstract

The electromagnetics course sequence in the Electrical Engineering (EE) curriculum at California Polytechnic State University, San Luis Obispo (Cal Poly SLO) is a rigorous subject that suffers from limited student interest and motivation. To remedy this problem, a set of lecture videos (mp4 files stored on dropbox.com) complete with concept presentations, example problem solution methods, dynamic field animations, and real-world applications were prepared to spark student interest in electromagnetics and help initiate new student projects. The videos were first introduced in Fall Quarter 2015. Although lecture video production is a well-explored subject, this paper describes the author's experience with this teaching method; issues in creating the videos – especially for less-computer savvy instructors – and their effect in changing student perceptions of the subject and motivation. Future directions include flipped classroom format implementation to enhance student interest in electromagnetics topics and applications, with accompanying concept comprehension and retention improvements.

Background and Introduction

The author has been teaching electromagnetics at the junior and senior levels in the EE curriculum at Cal Poly SLO for the past 15 years. He has been using the traditional lecture format, and has consistently observed students' apprehension toward the subject. The traditional one-way instructor-to-student lecture method has been shown to be a relatively inferior information conveyance technique relative to active learning (engaged student) methods[1]. A comprehensive meta-analysis (review of previous studies) paper[2] indicates that active learning (compared to traditional lecture classes) increases examination scores 6% and reduces the likelihood of failure by two-thirds. However, it has been the author's experience that in-class presentation of difficult course concepts is necessary to allow student-instructor interaction, questions, and class discussions. Once background in a particular concept is established, the flipped classroom method of in-class problem-solving and discussions can be pursued.

Lecture videos can help improve student motivation and information retention[1]. Hence, the author's objective is to present electromagnetics through methods compatible with today's internet-connected students. Lecture videos (.mp4 files) are stored on dropbox.com; first offered in Fall Quarter 2015. Another goal is to show students how this important subject directly relates to present-day applications (all wireless systems) and how it serves as the gateway to interesting and rewarding electrical engineering careers. Research has shown that actively-engaged students experience improved concept retention[3].

The junior-level electromagnetics course at Cal Poly SLO transitions students from electrical network analysis (sophomore-level circuits classes) to RF (radio frequency) transmission lines and an introduction to field theory. Students come to the class with a math background in vector calculus and elementary electricity and magnetism coursework in physics. However, this background usually lacks practical applications; hence, information retention is limited. The author regularly reviews basic subjects that students should know, but may have forgotten. These subjects include vector calculus solution methods, infinite series, and linear algebra including matrix multiplication and inversion. It is believed that students will not retain subjects which have limited real-world relevance. This is especially true for engineering (applied science) majors.

To overcome these retention issues, the author has developed a sequence of lecture videos that explains electromagnetics-related math and physics topics using practical examples including waves on ropes and Matlab wave animations, standing wave effects (cell phone reception), and microwave ovens (water heating by resonance). Through video-captured simulations and in-class demonstrations, it is hoped that students will link electromagnetics concepts to modern wireless systems and thereby retain these concepts in long-term memory.

A difficult topic in this course is graphical methods involving Smith Charts. Students have difficulties identifying movement along particular contours and applying general Smith Chart principles. Multiple lecture videos have been prepared to illustrate Smith Chart methods including basic "normalized impedance to complex reflection coefficient conversions" that convert between the complex normalized impedance plane and the Smith Chart. The most difficult hurdle is using the extensive grid on the Z version of the chart and the twice-as-dense ZY chart. Multiple lecture videos describe examples and applications on both versions to illustrate RF network analysis and matching network design techniques. These videos are followed up in class to reinforce these difficult subjects.

The author observed an improvement in student participation and insightful questions during problem-solving discussions. The in-class method involves projecting a Smith Chart onto a whiteboard and illustrating design procedures on the whiteboard. Class discussions in the most recent quarter's class have been especially lively. Questions came from nearly all students! It is believed that the lecture video background before class primes students on the subject – moderate, not quite full understanding – but sufficient background to ask relevant questions. Of course, class participation is also a function of student personalities from term to term.

Traditional Class Issues

The main problems observed by the author include limited prerequisite background retention and lack of preparation for class. Students do not read the book (or anything) prior to class. The first day of class includes an introduction to the course syllabus – a detailed schedule of course topics, relevant textbook sections, and homework and exam dates – and expected prerequisite background per the Course Catalog. To maximize course retention, students are advised to review topics before class. However, the only incentive is self-motivation. In the past, the author has witnessed only a few diligent students who carefully review material prior to class meetings.

The newly-created lecture videos are intended to help prepare students before class. The author is currently creating an online quiz for each video – administered through Cal Poly's PolyLearn (Moodle) online system – to test for student comprehension and reasoning (combining topics, limited analysis) relevant to the current day's subjects. However, without a grade weight, these quizzes are largely being ignored. The author has received only occasional student inquiries about quiz questions; hence, the benefits appear to be limited. Grade enforcement will be added in future terms when all quizzes are complete. This should provide incentive for lecture video viewing.

Another benefit of the lecture videos is to minimize student need for hurried in-class note-taking. Since the videos closely follow the notes and the author posts all notes online, students can avoid in-class note-taking by following along on the notes. Even with these accessible information sources, many students still take notes in class. Although there are benefits to note-taking (including retention), this activity could also take the students' attention away from salient points being explained by the instructor. The author is sensitive to student note taking, but this slows down the presentation. To solve this dilemma, the author presents basic information and relations needed for a particular topic, then presents the final result or property/relation. To bridge the gap, the author refers students to details contained in both the notes and lecture videos. This allows the author to maintain the pace required to cover all required topics, but does not "leave students in the dust" with limited understanding. The author follows up each discussion with relevant real-world applications to further enhance information retention. The author also verifies student understanding of the details through questions asked at subsequent class meetings.

After each lecture, students are expected to complete homework assignments to practice the newly-introduced concepts. This serves as an additional source of in-class discussion topics. Homework assignments include "supplemental questions" designed to probe more deeply into particular subjects and to require students to work through all steps in deriving electromagnetics principles and to identify required conditions or assumptions for each relation. This is especially important for engineers working on real-world projects, as many textbook design procedures assume ideal conditions. For example, linearization techniques assume a "sufficiently small" range around a particular operating point. For projects that do not conform to this requirement, linearization methods cannot be used. Hence, the author uses supplemental problems that require students to determine if particular analysis methods can or cannot be used.

The Flipped Classroom

Upon completion of online quizzes for all videos, the author will attempt to implement a flipped class in which students will be expected to review each lecture video, complete a quiz, and come to class prepared to solve problems relevant to the current day's topics. It is essential to present a brief review of lecture video topics prior to in-class activities[4]. Hence, the traditional lecture format is utilized for the first 10 or 15 minutes of class. This also helps the instructor identify topics that students find difficult to understand and could also help steer the in-class discussion. Multi-media examples will be added to further enhance student motivation[6].

Following the topic review, the author plans to pose discussion questions to the class and to form groups. This represents a major departure from the usual engineering class format and a redirection toward liberal arts-type classes. The discussion group format may be unfamiliar to students in engineering classes but the primary goal is to actively work together to solve discussion questions. This provides a real-world collaborative experience.

Video Creation

Lecture video creation can be an intimidating endeavor, especially for less computer-inclined faculty members (including the author). This section describes the difficulties and "I wish I knew that" topics the author experienced while creating lecture videos. Also included are software operational issues, required preparation time for each video, and .mp4 file creation and posting to online websites.

The author utilized Camtasia – available to all Cal Poly SLO faculty – which has extensive video capture and editing capabilities, because a 10-week Camtasia training course was conveniently offered through the university. The author's opinion is that a brief introduction (a few hours) is sufficient. Beyond this, video training classes prepare students for professional film-making, beyond the scope of most instructor video requirements. Video production objectives range from Hollywood blockbusters to "low-budget production-time-limited" instructor videos[5]. This reference also mentions TED talks in which highly-refined presentations are limited to 18 minutes, and Khan Academy which are low-budget, but well-organized and rehearsed. Videos that strive toward TED and Khan Academy quality, but within a reasonable investment of time and effort are recommended[5]. This author agrees with the recommendation; video production is time-consuming and requires a steady, conscientious effort to complete video production to the end of the term. Note that Cal Poly SLO is on the quarter system; semester system schools require a 50% greater effort. Good luck!

Video production efforts include two to three hours' preparation for each 20 to 30 minute video. This includes topic outline, handwritten notes, and pictures and animation preparations. Note that this does not include writing out a script, which is recommended in the video production training course. It is the author's opinion that although scripted videos are helpful for closed captions, they tend to produce "mechanically delivered" lectures which lack a natural flow and spontaneity. Instructor excitement and additional insight into the subject is limited; this could contribute to reduced student interest. Lecture video effectiveness also depends on the presenter's oratory skills.

Videos were produced for a 4-unit quarter system course; hence, 38 videos were created. This class meets 4 times per week for 10 weeks, less 2 midterms. The videos are between 20 and 30 minutes in length to cover material delivered in a 50 minute lecture. Video length decreased during the quarter, as the author attempted to limit video lengths to 10 minutes, as recommended by the video production course. It is the author's experience that 10 minutes is insufficient time to convey all course information. The Penn State study[4] used videos ranging from 10 to 50 minutes. Survey results[4] show that students preferred 20-minute length videos. The video production course also recommends short topic videos as opposed to complete class lectures. To save time (re-organization, additional production) and to follow the course syllabus, the author recorded videos that cover each in-class lecture. Video length was minimized (20 to 30 minutes), but all were longer than the training course recommended 10 minutes. Another reference[1] used videos with a 25 minute average length.

Each video includes a topic listing (relation to previous video, textbook sections, IEEE papers, application notes), industry applications (pictures and animations), detailed material discussions, and examples and additional applications. The author includes concept animations where appropriate (e.g.: traveling waves reflecting from and transmitting through material interfaces) to help visualize theoretical concepts. Videos can be replayed by the students following theoretical descriptions to improve the link between theoretical concepts and visualizations. The author recalls electromagnetics classes in which the chalkboard was filled with complicated equations with no connection to diagrams or industry applications. One of the author's objectives for university teaching is to provide students an understanding beyond equations while learning electromagnetics. Animations and diagrams presented in the videos are repeated in class to reinforce each concept.

Lecture Video Effectiveness

Student opinion on the lecture video effectiveness was quantified through an online survey in Fall Quarter 2016. Questions include:

1) What percentage of the videos did you watch? (36 videos total)
2) How many hours per week did you spend watching the videos?
3) Where did you watch the videos? At home, school, on the bus, other?
4) While watching the videos, did you:
    a. Take notes?
    b. Pause the video periodically?
    c. Write down questions when necessary?
    d. Re-watch sections when necessary?
    e. Other?
5) Lecture videos vs. traditional classroom. The lectures are:
    a. Much better than traditional class
    b. Better than traditional class
    c. About the same
    d. Worse than traditional class
    e. Much worse than traditional class
6) The lecture videos helped me learn course concepts
    a. Strongly agree, agree, no opinion, disagree, strongly disagree
7) General comments
    a. What did you like and/or dislike about the videos
    b. Length of videos: too long, too short, about right, other?
    c. Were the topic outlines helpful? Comments?
    d. Were the pictures and animations (dynamic pictures) helpful toward learning class concepts?
    e. How can the videos be improved?
8) What was your favorite part of the class?
9) What was your least favorite part of the class?
10) Overall suggestions for course improvement?

Students watched 59% of the videos, mostly at home (85%). 54% of the students also watched the videos at school. 85% took notes while watching the videos and 92% paused the video periodically, an overwhelming majority. This represents an important advantage of lecture videos. 15% of the students wrote down questions while watching the videos. While low, this helps initiate in-class discussions in the flipped class format.

Lecture video comparisons vs. traditional lecture were mixed. The results were:

1. Videos better than traditional lecture: 15%
2. Videos about the same as traditional lecture: 31%
3. Videos worse than traditional lecture: 46%
4. Undecided: 8%

The most consistent comment that helped explain the 46% "videos are worse than traditional lecture" results was that questions cannot be asked when a difficult concept is explained in the video. This is a distinct advantage of traditional lectures, especially for difficult concept courses such as electromagnetics. Students informed the author that live student-instructor interactions are important when learning difficult concepts. This is an important drawback to both lecture videos and online courses.

Student opinion on the "Were lecture videos helpful?" question were encouraging. The results were:

1. Strongly agree: 8%
2. Agree: 62%
3. Disagree: 8%
4. Strongly disagree: 8%
5. No opinion: 15%

While the above results are positive, the author is still striving to improve the lecture videos. While developing online quizzes based on previously-recorded videos, areas for improvement and corrections are being noted and applied. The above questionnaire will be distributed in future quarters.

Student opinion on likes or dislikes about the lecture videos include the ability to pause the video at any time and to provide material background prior to class meetings. Students also noted difficulties in following the notes and "jumping around" while covering lecture topics. These problems are being addressed and corrected during video review while developing the online quizzes.

Student opinion on video length were varied. The results were:

1. Videos were too long: 54%
2. Videos were too short: 0%
3. Videos were about right: 38%
4. Other: 38%

In the "other" category, student comments included:

1. Split them up on topics for mini-videos
2. The videos were long and dense
3. Need to be specific and on one topic (not several)

4. The videos were a good length, 15 min is reasonable, but taking notes took a full 2 hours. Became too much
5. Videos were more dense than lectures
6. Spend more time explaining concepts, not just doing math
7. Math is important, but not if we don't understand what the ### the math being done is about

Several student comments align with the video production course recommendation on producing concept videos. This is a future goal for the author. The "videos more dense than lectures" comment aligns with the author's goals. Top-level topics and outlines are explained in-class, while detailed information and derivations are discussed in the lecture videos.

Overall comments include:

1. A lot of work to add to homework problems
2. Good resource, but 1 hour per video + lecture + homework is a lot
3. Helpful, but long and dry
4. Hard to get through and stay engaged
5. They double the hours a week I spent on lecture
6. Good start! Don't give up.

The author is sensitive to adding required time to already overburdened students. Online quizzes add to this load. The author is working to understand this issue and possible compensating measures. Students have commented to the author that although it is more time and effort, they prefer this format. This may not necessarily denote the majority opinion.

It is interesting to note that the most prevalent student comment for the "Overall suggestions for improvement" question is "less workload." The subject of electromagnetics requires substantial effort in both understanding course concepts and applying and practicing these concepts while solving problems. To achieve the required level of understanding for subsequent electromagnetics (electrodynamics) and technical electives (wireless systems), the student must be prepared to invest substantial time and effort. Variable student capabilities affect this required workload, but the required effort is nevertheless substantial for all students.

An important issue for instructors when deciding to produce lecture videos is "Is it worth all of the effort?" In this author's opinion, in comparing traditional lectures to the supplemental online lecture video format, it is recommendable to pursue video production. If a few students are positively influenced by the revised format, it is worth the effort. The videos and quizzes serve as additional methods to improve student motivation and concept retention.

Future Work

The author is committed to completing an online quiz for each lecture video and following through on video corrections and improvements, including decreased video length. Concept videos, as opposed to in-class lecture videos and additional problem-solving videos will be explored. If possible, student performance comparisons between traditional and flipped classroom formats will be explored if the author is assigned multiple sections of this course.

Correlations between questionnaire parameters (e.g.: number of videos watched) and exam performance can be explored; however, this requires respondent identification, which may substantially reduce the number of completed questionnaires and truthful (honest) answers.

The author is hesitant to completely convert to the flipped classroom format. For difficult subjects such as electromagnetics, it may not be recommendable to assume students sufficiently understand each lecture's concepts to solve example problems. This requires a return to traditional lectures to carefully explain these involved ideas, which include instructor-student interactions to ensure student comprehension. It is hoped that previewed lecture videos will provide an introduction, followed by in-class instruction to move toward a more complete understanding.

The author hopes to institute a hybrid format between traditional lectures and the flipped format. For less difficult concepts, the author may use the flipped format directly. However, for many subjects, the traditional lecture format is required to maintain satisfactory progress through course topics. The lecture videos can be used by students after in-class lectures to review difficult ideas and also to review and prepare for exams. Hence, the author believes that video production is a worthwhile endeavor.

References

1. M. Stickel, "Teaching Electromagnetism with the Inverted Classroom Approach: Student Perceptions and Lessons Learned," 121st ASEE Annual Conference and Exposition, Indianapolis, IN, June 15-18, 2014
2. S. Freeman, S. L. Eddy, M. McDonough, M. K. Smith, N. Okoraofor, H. Jordt, M. P. Wenderoth, "Active Learning Increases Student Performance in Science, Engineering, and Mathematics," Proceedings of the National Academy of Sciences USA, 111, 8410-8415, April 2014.
3. F. T. Arslan, "Improved Flipped Classroom Teaching for Electromagnetic Engineering Course," Proceedings of the 2015 ASEE Gulf, Southwest Annual Conference, The University of Texas San Antonio, 2015
4. S. Zappe, R. Leicht, J. Messner, T. Litzinger, H. Lee (2009). "Flipping" the classroom to explore active learning in a large undergraduate course," Proceedings of the 2009 Annual Conference of the American Society of Engineering Education.
5. D. Bolliger, S. Supanakorn, and C. Boggs (2010). "Impact of podcasting on student motivation in the online learning environment. Computers & Education," 55, 714-722
6. P. Johanes, Lagerstrom, L., "Online Videos: What Every Instructor Should Know," ASEE 123rd Annual Conference & Exposition, New Orleans, LA., June 2016, 17 pages.