# *No More Lecturing In Engineering!*


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## *Lecture-Free Engineering*


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*There are numerous references in the engineering education literature to how effective 'active learning' is [1] and how our traditional lecture style is not necessarily the most effective way to teach. I've tried active learning in my own classes for the last several years, mostly having the students work in small groups on examples, collecting questions, etc. [2]-[4] But I haven't been able to escape the 'sage on the stage' lecture paradigm, because in engineering it seems as if they students need a certain amount of basic information before we can have effective discussion, group work, etc. So, I this paper describes my (I think extremely successful) experiment using video lectures to augment my traditional teaching. This paper describes my experiences, and the method I am currently using to teach a large (58 person) required undergraduate electromagnetics course without traditional in-class lectures. I record my lectures on a tablet PC in advance of the class and upload them to YouTube. Students watch them before class. During class, I try to help them make the transition from lecture to homework, hopefully helping them gain better problem solving skills and strategies. I do this by having them begin the homework in small groups (2-3), wandering the class, and then bringing them back together for discussion of critical questions and interesting points. I hope to help them reach higher level thinking skills as well through this process and discussion. From the level of questions received, I believe this is happening, although I have no test data to prove it. I also have time in class to discuss an engineering application of the principles we are discussing that day. By the time they leave class, we have generally set up (but not fully solved) all or most of the homework problems and had a discussion about applications of the ideas. Many students later go back to the videos for further clarification while completing the homework.*

*This work should be considered a pilot project. The assessment I have is all self-reported student evaluations (including several mid-semester evaluations) and observations by a professional evaluator from our Center for Teaching and Learning Excellence. Test scores showed no significant difference from one year (not using this method) to the next (which did). Student course evaluations were dramatically higher when using this video lecture method, and comments were highly supportive of the approach. Additional evaluation and experimentation is needed to determine the very most effective approach(es) to this method, both the video content and the use of class time.*

## *Here are the details of what I have been doing:*

***ECE 3300 Introduction to Electromagnetics*** ***[6]*** *is our required junior-level EM class. Typically 50-as many as 102 students are in this course. This is a mathematics-intensive electrical engineering course. The website* ***[6]*** *includes examples of both tablet-based and white-board based video lectures, as well as homework assignments, lecture notes, etc.*

1) The Video Lecture: *I use a standard HP tablet PC, nothing fancy. I created a power point template (which is linked to every lecture on the class website [6]) which has the university logo (I'm happy to give the lectures away free, but I like to be sure the university gets credit for it, hence the template) and (very important) some thin blue lines that help guide my writing in a more or less straight line. I am a pretty sloppy writer, so I have to take some care to keep it legible on the tablet or on the board.*

   *I do the lectures in 5 minute segments using a software called 'Jing' . [7] Jing can only support 5 minute lectures, but another software called Camtasia [9] can support much longer ones. Typically it takes 4-6 segments each 3-5 minutes long to complete a lecture when you are not interrupted by questions. The students generally say they like the shorter format, because they can easily go back to topics they want more review on. From querying the students, the format I have decided to use is to create one summary section, which is included at either the end of beginning of the lectures. Some students choose to look at it first, others at the end, and some in both places. I go as fast as I can through the material, because if the students want to slow it down, pause it, or hear it again, they have that control in the video player. I try not to repeat myself, because they can repeat me if they didn't get it the first time just by moving the slider back. It takes me about an hour to record 20 minutes of video because of going back multiple times when I don't like the way I am explaining something (a 'rewind' I couldn't do in class on the board!) When I first started recording, it took me longer. Notably, when I make a small mistake (which the students usually catch), I haven't been going back and fixing it (I don't have time). Instead, they or I just leave a 'comment' on the YouTube site to correct it.*

   *Then I upload the videos to YouTube [9]. YouTube lets you upload as many videos as you want to, each under 10 minutes, free. The Jing software will let you do an automatic upload, but I prefer to do it manually when I have recorded all of the lectures for one day, mostly because my home internet is intermittent and slow. Be sure to choose a naming convention for the title of these videos so they make sense and can be found. I use ECE3300 Lecture 1-3 Topic so the students can sort by class, they can see this is Lecture 1 Part 3 (I would use the 'Part' in future naming), and the topic can also be searched on YouTube automatically (students from all over the world use these videos now, for instance). One of my colleagues creates 'playlists' for each lecture, which I think is a great idea. You can also include keywords, etc. to help people find your videos. I link them to my class website. I also upload the power point file associated with each lecture. Many students print these out and take additional notes on them, sometimes on their own tablet PCs.*

2) In Class: *I prepare another set of power point slides for the lecture time each day.*



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*These are NOT the same slides used in the video, although some of the content may be the same. In these slides I include the major equations, so I can easily put them up on the screen, and each of the homework problems, so I can refer to them, and anything about the solution I want to be able to refer to, and also pictures or whatever I need to discuss the engineering application. I don't include these materials on the website because a lot of it is copyrighted (the problems from the book, for instance). I teach in a classroom that lets you project up on the side screen while still having full access to the blackboard. So I project the slide on the side screen and use the central part of the board for working out the solutions, etc.*

3) In class student-driven review. *Typically I start the class by putting up my portfolio question for the day. That is really a question that the lecture is answering that day such as 'How do you design a single stub matching network'. I then have the class walk me through the answer to the portfolio question. Often I write this on the board on the other side of the classroom, particularly if it involves steps we will later use. Other times I have written these steps on a later slide and refer to it after the students have pulled from memory or their notes all of the steps they can. I like writing it on the board better. This all takes about 5 min and is more or less a student-driven review of the previous nights' video lecture.*

4) Active small group work. *Next I put up a problem (usually from the homework) they should be able to solve with the steps or method we just wrote down. Often I have this on a slide, particularly if it has a figure. Most students have their books with them, and refer to those as well (easier to see the details). I ask them to get in groups of 2-3 with their nearby neighbors and set up the problem. If the problem has several steps or parts, I get them started on the first part or two, not the whole thing.*

*When I first do this (first week or so of class), students are reticent to actually work with their neighbor and will quietly start doing this on their own. As I walk around the classroom, I actively bug them to move over and work with this person or that person. One student said he learns much better alone and was very resistant to this. So I bet him lunch that he would learn something from any student I put him with, he moved over with another group, and when I asked him afterwards, he said he owed me lunch. Usually once students try this, they really like it, but I had to be quite (cheerfully) aggressive to get some of them to try it.*

*So I walk slowly around the class, act interested in what each group is doing, kind of look at their papers (not slyly, head on), ask how they are doing, did they get it, what was the plane of symmetry, anything. The fact that I am interested in what problems they are encountering often gets them to stop me as a wander by and semi-privately ask me a quick question. I may answer it right there, or (particularly if it becomes apparent it is a common question), I may answer it for the whole class. It seems to take about 2 minutes for them to get far enough into the problems to ask questions. Depending on how they seem to be doing, I usually let them go for 4-5 minutes. I may interrupt earlier if it becomes apparent many are stuck, usually about on the same step. If they aren't writing, they are stuck. If they aren't noisy (talking with each other) I probably need to help them get unstuck. I don't usually leave them alone for more then 4-5 minutes without interrupting to ask for specific observations ('as you move away from the line of*

*current, how does the magnetic field change', 'would this field penetrate a metal box', etc.) Most problems take longer than 5 minutes. The 5 minutes is probably enough to get one part of the problem pretty much set up. I'll write the set up on the board, generally pulling it from various student groups with specific questions … what do I do here, what do I do next, etc. Then we move onto the next part of the problem and work on that until it is set up, and so on. Most of the time they haven't actually calculated the numbers but will do that at home.*

*The slow walk around the classroom collecting questions and observing problems is one of the important aspects of this method, I think.*

5) Applications. *One of the things I really wanted to be able to do was show the class how the sort of abstract concepts they learn in class apply in real applications. So almost every day I could bring in an application (usually with photos, videos, etc. that you can now readily find on the web), talk about how it works, and either tell or ask the students how what we are learning that day apply in that application. I would put links or various support on the web, and many students were going to these links later to learn more. Eventually I would like to have an application a day. This does take some time to collect.*

## What I want to do from here:

*Next year I am going to add incentive to watch the lecture before class by having the students turn in the portfolio answer (for credit) for the day in class and not accept it late. If a student is missing class, they can submit it electronically. If they have work conflicts, the lectures are all there and they can watch them the weekend or whenever in advance.*

*I will also ask them to write down any questions they have after watching the lecture but before coming to class, and will make video or written responses in a 'frequently asked questions' section for each day.*

*I also hope to add more examples of how to solve the problems, perhaps do videos of solving old exam problems, with explanations, for instance.*

*Some of my lectures could be improved, so there is always room for continual improvement and adding here. Now, at least, I know they will get better and better and not leave out something different the next time!*

*I had also hoped to create these lectures with a few colleagues who were also teaching the same class. But they got busy and didn't help after all. I hope to have a colleague try these with her class, and see if they work as a transition from faculty to faculty or not. Probably if several different faculty had videos, a student who was confused might get help from another faculty's videos.*

*Eventually I would like to create a free online (but at least partially printable) textbook to go with*



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*this, teaching things the way I usually choose to teach them. This would be a downloadable PDF file, with each video segment linked to that part of the written material as done in this online emagazine. [10] There would be plenty of color pictures and videos, including Matlab codes linked for the students to run. The applications of interest would also be linked. And since these would be links and not downloads, copyright would not be an issue. Maintaining the links probably would be, but there is software now that can help quickly identify broken links. Most applications have multiple links you might choose anyway. If a student wanted a printable textbook, the PDF could be linked to an online printing site such as lulu.com to be printed inexpensively in color or BW, hard or soft cover, even large or small print. Or they could print it on their home printer or any other print facility. I would like the flexibility of updating resources such as the textbook as I go, adding things from conferences I attend, other research tidbits, etc. I would like to be able to 'write in the margins' to highlight the important aspects along with the lecture.*

*In class eventually maybe most of the students will have tablet PCs also, and we could use the wireless internet in the classroom to quickly display an individual groups' work solution to setting up a problem, allowing direct discussion of what a group has done. I would like to be able to do this, because often I get different parts of the classroom solving the same problem but with different parameters in order to demonstrate how different parameters affect the solution.*

*I would like to expand this method to the basic math and science classes (chemistry and physics) that tend to plague our students and often result in them dropping engineering. A 'gifted' teacher could provide the lectures and even the in class discussion content, which could then be broadly used by less experienced or less gifted teachers. Even if a teacher did not choose to use this material in their class in any way (a very traditional teacher, for instance), it would still be there as support when students tried to do their homework.*

*I would also like to see this method expanded downward into the high schools or even lower, covering the math and science concepts that students find challenging. In these grades I have a hunch that it would be very difficult to get all of the students to watch the lectures before class, and that in class lectures of sorts would still be needed. But I think it would be extremely helpful for these students to have the lectures available after the class when they are trying to do their homework, and perhaps struggling with it.*

*There are many opportunities these videos could provide. For instance, if you were trying to teach freshmen or other relative novice students how to take better notes, you could have two screens … one playing the lecture, and the other demonstrating what an experienced note-taker would be writing as the lecture progressed. You could also add 'balloons' in the lecture itself (YouTube lets you comment directly on the video as it plays) to show what the professor is 'thinking' and the 'cues' a student should pay attention to in a lecture.*



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## How I would start a class like this.

*The first time I did this, I made videos of the last third of class. The second time, I did the front 2/3. That seemed to work well. I would start at the back of class rather than the front. Once you do this, if you don't do it all the way to the end of the semester, the students are likely to be displeased. If you start nearer the end, they will be happy with what they do get.*

## *Evaluations:*

*I asked the students to give me written feedback in weeks 1,2,3,4. We did a formal assessment of the class in week 7. I had a professional evaluator sit in and evaluate the course when I taught it this way and also when one of my graduate students taught it this way (professional teacher vs. novice teacher). I was specifically mentoring this graduate student in this teaching method, which provided interesting observations on what she and I were doing differently.*

*The feedback from the students was almost unanimously positive about this method. They did provide a lot of specific feedback on method, details, etc., which I will be glad to share with other professors who are working on this method.*

*The end of semester course evaluations from two years are given here. In 2007, I did video lectures on a white board for about the last 1/3 of the class. I did regular lectures in class and posted these after the class period. In 2009, I did video lectures on the tablet PC (and used the teaching method described above). Values are given on a 6.0 scale with 6.0 being 'Strongly Agree'. Student comments again strongly supported the videos, with constructive suggestions I will also be glad to share with participating professors.*

| Student Evaluation scores: | 2007 | 2009 |
|---|---|---|
| *Overall this was an effective course* | *4.98* | *5.68* |
| *Overall this was an effective instructor* | *5.13* | *5.85* |

## *Conclusion:*

*I believe this pilot project was extremely successful. I intend to continue to teach this way, and never plan to go back to 'regular' lecturing again. I will be glad to mentor other professors interested in developing materials of this sort and using them in their teaching, provided the materials are made available publically for use by other students.*

*Some of the more popular topic videos have been watched numerous times by students all over the world. The most popular is (by chance) on Gaussian Elimination, and has been watched over 15,000 times.*



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*I get numerous comments each week thanking me for providing these video lectures. I think this free and available access is one of the critical elements to providing a true transformation in undergraduate education.*

## *History and Other Things I Have Tried:*

***Year 1: ECE 5340/6340 Numerical Electromagnetics (senior/grad level elective, about 30 students) [5]***

*I had one student who was not able to attend class because of conflicts at work. He started the semester by having one of his friends video-tape the course using a DVD-based video camera on a tripod. We quickly found that it took a professional level videographer to make it easy to see the board, and this made it so his friend couldn't take notes at the same time. So I started recording the lectures quickly after class in my office with my own small handheld camera (not even a 'real' video camera) on a white board. The white board showed up better than the blackboard, but still not perfectly, so after every 'full' whiteboard, I took a snapshot with the camera, which I uploaded to the class website in *.jpg form along with the *.mp4 video file. I chose *.mp4 so they could upload it to their ipods, which students began to do. I generally posted the lectures the evening after class. I noticed that attendance in class dropped slightly, and when I asked the students about this, it was because they could watch the videos after class, and if they were busy at work or had other conflicts, they might not drive in to the university to attend class (about half of the students in this class were working full time or nearly full time as engineers or interns). The students liked having these lectures as reference material when they were trying to do the homework. They were posted in 5 minute increments, typically 20-30 min per lecture total, because that is about how long it took to fill the small white board I was using.*

*Next, out of curiosity, I started posting the lectures before class, and asked the students to take a look at them before they came in, so we could discuss questions in class. About half of the class did this. I still did a traditional lecture in class, essentially repeating the material in the videos, and we discussed it and answered questions. There were a lot more questions than usual this way (I'd guess about 20-30% more), and attendance returned to its usual level. The students commented that they would watch the lecture before class, fully intending not to come to class. Then they would see it was a little harder than they thought, have a number of questions, and decide to come to class after all. The discussion was often lively, and we didn't usually have enough time to get through all the questions. I also experimented with uploading lectures to YouTube at the end of this class, and students really liked that, because they didn't have to download the full videos themselves, they could be streamed off YouTube, which made it easier for slower internet connections.*

***Year 2: ECE 3300 Introduction to Electromagnetics (required junior level course, about 60-65 students) [6]***

*Near the end of this class (about the last 1/3) I experimented with recording lectures for this large undergraduate course. My original intention was to give them a video reference they could quickly refer*



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*to when doing their homework, sort of an instant professorial recap. I again recorded them on the white board, quickly, and tried to post them on YouTube before class. Sometimes I got behind and posted them afterwards. The students really liked having this reference material, and I could count the student usage and watch it with time. It appeared that few students (less than 10%) watched the material before class. In class I always did a lecture that was essentially a recap of the material in the videos. The majority of students did refer to one or more of the video sections when working on the homework, however. Some of the videos covering more difficult parts were watched 2-3 times as many times as I had students in the class. These were a very popular addition to the class.*

*At this point, I could see the problem with the traditional lecture method. The students basically sat passively taking notes while I lectured. They stayed awake, because I am a pretty energetic lecturer, but they were not unusually engaged. I broke up the lecture at least every 15-20 minutes, to have the class work parts of the examples in small groups, for instance, to keep everyone alert. Then the students would go home to do their homework, and would often ask questions later that made it clear they hadn't made the leap between the basic lecture material and the problems they needed to solve. They often solved the problems by 'equation shopping' (looking for and applying the applicable equations without a lot of thought as to why you might choose one set of equations over another. The active part of their learning was at home by themselves, working on their homework. They often had questions, and I wasn't there to help. I was frustrated that I had only a little time at the end of the lecture to include the more advanced problem solving skills, the deeper meaning of the equations and ideas, and the engineering applications.*

***Year 3 (this year): ECE 3300 again***

*So this year I have made a significant change in how I teach this class. I NO LONGER lecture in class. Instead, I record the lectures in advance using a tablet PC (thus eliminating the videography problems of seeing the board), the students watch it before class (about 70% watch it before class, 80-90% by the evening of class), and I do NOT do a lecture in class. I don't repeat the material the students are supposed to watch on the video. In class, we answer questions, have a discussion, start their homework (typically setting up most of the problems they are going to solve), and discuss an engineering application. The number and nature of questions I receive is significantly increased. From these questions, I think the students are much more engaged, and are thinking at a higher level. We do the homework in small groups (active learning), and questions quickly emerge, which I answer for the whole class. This method has given me extra active time with the students, seems to be much more engaging and fun, and gives me time to help them with problem solving strategy instead of just equation shopping.*

## *My Other Educational Initiatives*

- *Department-Level Reform: System-Level Design Curriculum*
- *Write-to-Learn in Engineering*
- *Outreach, Recruitment and Retention*
- *Electromagnetics Education*
- *IEEE Women in Electromagnetics*

*Related Publications*

## *References*


*[1]* http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Student-Centered.html

*[2] Thirteen crazy, notorious things to do in an EM class, Volume 47, Issue 3, June 2005 Page(s):133 – 134*

*[3] Teaching and learning combined (TLC), Volume 45, Issue 3, June 2003 Page(s):166 – 167*

*[4] Take a stand: speaking about RF safety, Volume 46, Issue 6, Dec 2004 Page(s):146 – 150*

*[5]* www.ece.utah.edu/~ece6340 *(FDFD, Matrix solution, MoM sections)*

*[6]* www.ece.utah.edu/~ece3300 *(first 2/3 of class)*

*[7]* http://www.jingproject.com/ *>> This software is free, but you need the 'Pro' version, which costs $15/year I order to record *.MP4 files that upload automatically to YouTube.*

*[8] www.youtube.com*

*[9]* http://www.techsmith.com/camtasia.asp?gclid=CMGdzY7N5p0CFR4Uagod00VbMQ

*[10]* http://www.horselinkmagazine.com/home.html




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