Flipping the Classroom for an Advanced Controls Course with Lecture Video Modules

Abstract:
The difficult nature of the Controls subject and the brisk coverage required at ECU (as a result of a general engineering program) pose a great challenge for both the instructor and the students when either teaching or taking EENG4510—Control Systems Design. This course requires advanced mathematical skills such as calculus, differential equations, and beyond. It is a highly abstract course that makes it impossible for students to preview by reading the textbook. Therefore, the majority of the students often do not comprehend when the material is first introduced. As a result, teaching/learning is often burdensome, time consuming, and ineffective. The “Flipped classroom”, where lectures are provided beforehand and in-depth discussion occurs during the scheduled class meeting times, appears to be a viable solution to the problem. Recorded lecture videos can explain challenging concepts in meaningful ways and boost student comprehension. After watching these videos (multiple times when needed), the students are prepared to pointed questions; in-class discussion is therefore more effective. We may even move directly to problem-solving in classroom discussion, which leads to a higher-level learning than when just new content is introduced.

The overall goal of this project is to encourage active learning and improve learning efficiency with innovative “flipped classroom” pedagogy. More specifically, I propose to develop a series of (25) carefully-prepared lecture videos for EENG4510—Control System Design and incorporate the modules into future instruction. These new modules will impact multiple other closely-related courses. Helpfulness of the material and learning improvement will be evaluated with instruments such as student work examples and a student survey; data collected will be analyzed using statistical comparison methods.
**Purpose/Objective**

The purpose of this project is to (1) encourage student active learning and (2) improve learning efficiency in *EENG4510—Control System Design* and several related courses. This overall goal is achieved by incorporating carefully prepared lecture videos into day-to-day instruction and facilitating in-depth classroom discussion. Specific objectives for Summer 2016 are to develop (design, record, edit, etc.) a series of (25) lecture videos for *EENG4510—Control System Design*. Other objectives include disseminating the developed material (and the pedagogical approach) to other instructors and other courses (*ENGR 3050—Sensors and Controls* and *EENG 3020—Signal and Systems*) and evaluating learning improvement brought by the intervention.

**Project Description**

Traditional instruction methods often begin with instructor-guided lectures during regular meeting times followed by student practices such as homework assignments. The “Flipped Classroom”, also known as “flipped-class” or “reversed-classroom” [1,2], inverts this sequence by having the lectures (often recorded videos) prior to the normal class meeting times then allowing high-level discussion and problem-solving when meeting in the classroom. This pedagogy, if utilized appropriately, can improve learning effectiveness and has been widely adopted by the engineering education community [2-3]. At ECU, similar efforts [4-8] have also been funded during the last three years for the purpose of enhancing student learning in a variety of disciplines.

If funded, I plan to prepare a total of 25 videos that deliver the learning outcomes defined in the *EENG4510—Control System Design* course syllabus: theories of two categories of design methods and modern digital control systems. The initial list of the videos includes:

1. Introduction to Control Theory and its Applications
2. Control System Performance Review
3. Root Locus and Manually Sketch Root Locus (2 modules)
4. Connection Between Root Locus and System Performance
5. Control System Design via the Root Locus Method (3 modules)
6. Frequency Response of Control Systems: Bode Plots and Nyquist diagrams (3 modules)
7. Manually Sketch Bode Plots and Nyquist Diagrams (2 modules)
8. Connection Between Frequency Response and System Performance (2 modules)
9. Control System Design via the Frequency Response Method (3 modules)
10. Introduction and New Concepts in Digital Control (3 modules)
11. Digital Control System Design (4 modules)

The textbook comes with power-point (PPT) resources that can serve as a starting point for the project. In order to make the videos more effective, several strategies will be taken when producing the PPT-based video modules. First, the length of the videos will be kept no longer than 30 minutes so that the students can conveniently insert these modules to their busy schedules yet achieve expected learning outcomes. Secondly, an overall organizational map will be included to provide a clear pathway that can orient the students at different stage of the course. It will also help them understand the relationship between different modules. Thirdly, the videos, in addition to the intended technical topics, will include the following features to gauge student progress and guide their next steps: (a) A Prerequisite slide that specifies material that must have been mastered prior to entering the module; students who feel that they have not mastered the prerequisites are directed to the corresponding earlier lecture modules. (b) PPT animations that logically connects new material to the students’ prior background. (c) A Summary slide that revisits important points covered in the module in order to offer a spiraled learning experience. After the videos are developed, they will be incorporated into the day-to-day instruction as part of the pre-class requirements. Quizzes based on the videos will be given at the beginning of each lecture to encourage the students to watch the videos.
Need and Impact

Controls is an essential part of the Electrical Engineering (EE) curriculum. A survey of the Engineering Department Industry Advisory Board (conducted before the establishment of the EE Concentration in 2010) revealed that Controls (and Power) are the two skill areas for which regional employers have the most need. Due to the abstract nature and the extensive mathematics involved, students usually find Controls courses extremely challenging. Still, the breadth of ECU’s general engineering program (which, as suggested by its name, has a broader curricular coverage than other specialized engineering programs) requires these courses to be taught in a streamlined fashion. During the last three offerings of EENG4510—Control System Design, I have experienced the challenges from the brisk coverage of this difficult course and witnessed the students’ struggle. The proposed “flipped-classroom” should greatly improve this course. Due to the strong connection between courses in the curricular sequence, lecture videos from this project will help several other courses as summarized below. It will directly benefit about 210 students every year as shown in the table. As the engineering department grows, we anticipate a more significant impact from these video modules in the future.

<table>
<thead>
<tr>
<th>Course</th>
<th>ENGR3050—Sensors and Controls</th>
<th>EENG3020—Signals and Systems</th>
<th>EENG4510—Control System Design</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual sections and enrollment</td>
<td>7×20 = 140</td>
<td>1×35 = 35</td>
<td>1×35 = 35</td>
<td>210</td>
</tr>
</tbody>
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Schedule of Activities and Their Proposed Deadlines for SS1

I have made several lecture videos for other classes similar to what is proposed here. On average it takes 5-6 hours to make a 30-minute module (prepare slides, design animations, and rehearse and record videos), which results in over a hundred and fifty hours just to record the 25 videos. Many more hours are required to edit the videos to achieve the desirable effect. This obviously requires a significant commitment that cannot be given in spring/fall semesters because I usually
teach three courses with active research projects and other service duties. Six weeks are planned for the module development. Expected completion time will be June 31, 2016.

<table>
<thead>
<tr>
<th>Weeks 1-3</th>
<th>Regroup and modify the PPT files provided by the textbook</th>
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<tr>
<td>Week 4</td>
<td>Rehearse and record lecture videos</td>
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<tr>
<td>Weeks 5-6</td>
<td>Edit, finalize, and produce modules</td>
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</tbody>
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**Evaluation Plan**

The helpfulness and learning improvement resulting from these modules, as well as students’ perception, will be assessed with student work samples (homework and project reports) and a student survey. Questions will include the examples below as well as open-ended ones.

1. Did you watch all the lecture videos?  
   a. All   b. Most of them   c. Some of them   d. None

2. Overall, how useful do you think these lecture video are?  
   a. Very Helpful   b. Somehow Helpful   c. Not helpful at all

3. Did the videos make your use of time more efficient?  
   a. Definitely   b. Somehow   c. Not at all

4. How were you prepared for in-depth classroom discussion after watching the videos?  
   a. Completely prepared   b. Somehow prepared   c. Not prepared at all

5. How ready were you to solve problems after watching the videos?  
   a. Could complete homework problems immediately  
   b. Usually able to work on homework problems with minor questions  
   c. Had some ideas about how to start homework problems but much additional help needed  
   d. Usually had no idea about how to start homework problems

When appropriate, other assessment ideas (such as those in the reference [9]), although not listed here due to space limitation, may also be adopted. Results will be compared to data from the past three years.
Appendices

(a) List courses you teach and your scholarly interests that are relevant to this proposal. If you have release time or compensatory time applicable during the proposed project period, provide brief details.

COAD 1000 – Freshman Seminar Series
ENGR 1012 – Engineering Graphics
ENGR 1014 – Introduction to Engineering
ENGR 2050 – Computer Application in Engineering
ENGR 3014 – Circuit Analysis
ENGR 3050 – Instrumentation and Controls
ENGR 4501 – FE Review Session
ENGR 4510/4520 – Senior Capstone Project Series
EENG 3530 – Electronics
EENG 4510 – Control Systems Design
MENG 4350 – Electromechanical Systems
ITEC 6000 – Statistics Applications in Industry

I have developed many courses over the years. Research results and practices from these efforts have resulted in many publications in conferences and journals, with a few examples included here. I have also been funded by NSF (“Portable Cyber-Laboratories: Virtual Instruments and Affordable Prototyping Kits to Enhance Learning and Improve Access to Electrical Engineering Education”) to develop and test portable experiment learning tools for electrical engineering courses.


(b) List all proposal titles and dates of grants previously funded from the Committee.


(c) If consultants are to be used in the Project Expense Grant, give credentials and your rationale for hiring them.

*N/A.*

(d) If project involves attending a workshop or seminar, attach a copy of the flyer or announcement.

*N/A.*

(e) IRB approval or evidence of application to IRB

*Since surveys will be administered to students and instructors as part of the evaluation plan, I am aware of the possible need for IRB approval. I have gone through the IRB process many times for other research projects and therefore understand all the steps to obtain it. If a positive funding decision is made, I will work with the IRB office to go through all the procedures. If IRB is needed in this project, I believe the process will be expedited.*

(f) References

[1] Gregory Mason, Teodora Rutar Shuman, Kathleen E. Cook. Inverting (Flipping) Classrooms – Advantages and Challenges, the 120th ASEE Annual Conference and Exhibition, June 23-26, 2013, Atlanta, GA


[4] Instructor: John Kros; College: Business; Proposal Title: Online Instructional Videos for Spreadsheet Modeling: Aids for OMGT3223 Students; Year: 2013

[5] Instructor: Megan Janke; College: Health and Human Performance; Enhancing Students’ Learning through the Use of Video Resources (RCTX 4252: Recreational Therapy Leadership and Group Dynamics); Year: 2013


[7] Instructor: Christy Walcott; College: Psychology; Proposal Title: “Flipping the Classroom” with a two- course assessment sequence; Year: 2014

[8] Instructor: Karen Vail-Smith; College: Health and Human Performance; Proposal Title: Core concepts video library for HLTH 1000; Year: 2015