SYSTEMS ENGINEERING (ESC161/ESC251)

Systems Engineering is the first course in a two-course sequence required for mechanical engineering majors. This course is an introductory course to the mathematical modeling of systems. The modeling of systems is an interdisciplinary skill and the course has attracted engineering students from outside the ME department. Students learn how to model a variety of systems, including mechanical, electrical, fluid, thermal, and mixed systems (such as electromechanical), and solve for the system's response using differential equations and Laplace Transforms.

When I first began teaching this class I developed PowerPoint slides for lectures but I quickly realized that students learn concepts best from traditional chalkboard lectures. I now reserve using PowerPoint for occasional illustration of real-world applications. I still post the PowerPoint slides I developed on the ESC251 online course website (Moodle) as an additional resource, which the students seem to like to use as a study guide. Instead of entirely lecturing to the students, I reserve some class time for solving problems on their own so students become active learners instead of just passively copying notes. I also encourage lively discussion on how to approach problems and I also give frequent anecdotal accounts of how the theory they are learning relates to the real world. I rarely assign any textbook problems as these can be dry and only illustrate concepts without any real-world context. Instead I write many of my homework problems and exam problems within the context of a real-world example.

Numerical modeling and analysis methods and MATLAB/Simulink are widely used in research and industry − in fact, I used MATLAB/Simulink to develop system analysis tools for my Ph.D.and for part of my work as a Powertrain Systems Engineer at Chrysler.Consequently, I introduced a week-long MATLAB/Simulink computer classroom seminar in ESC251 to give students time to develop skills in programming and simulation. The students are assigned a tutorial and an extensive MATLAB/Simulink assignment. This assignment is many students' first in-depth exposure to MATLAB/Simulink and students have to simulate and analyze a system numerically. While some students recognize that MATLAB is a great skill to have and are excited to have an opportunity to learn it, some struggle through the assignment. However, on multiple occasions, students have come to me after taking my course to let me know how useful developing MATLAB skills in my courses has turned out to be. For many, these MATLAB skills prove very useful in summer internships or their first jobs, for modeling and data analysis in subsequent research projects, and elsewhere. Below is an excerpt from an email from a student after taking my course:

> *"My internship at Southwest Research Institute has been going really well so far. I have 3 more weeks left here and I'm sure it's going to goby very quickly. They were impressed with my MATLAB skills and knowledgein controls and vibrations. It's been a great opportunity where I've beenable to use the theory from most of my ME classes. So even though we mighthave complained about the lengthy MATLAB assignments in Systems, they wererealIy important in building up my proficiency and confidence in MATLAB.Thank you."*

With my election as Chair, I am now working with Prof. Luchtenburg to improve Systems Engineering and add continuity to and assess our MATLAB/Simulink and numerical methods instruction in ESC251 and ME351 as well as in our new required Dynamics, Vibrations and new elective Modern Controls courses.

Included in the portfolio are the following supplemental documents related to ESC251:

1. ABET course syllabus
2. Student SALG course survey results (aggregated from 2012, 2013, 2014 and 2016)

FEEDBACK CONTROL SYSTEMS (ME351) AND *NEW* CO-REQUISITE PROCESS CONTROL LABORATORY (ME352)

Feedback Control Systems (ME351) builds upon the modeling and analysis learned in Systems Engineering (ESC251), teaching students various methods of analyzing and controlling dynamic linear time-invariant (LTI) systems. I teach traditional feedback control concepts, such as root locus and frequency response methods, via a traditional chalkboard lecture approach, but I augment the traditional approach by assigning computer simulations using MATLAB and showing practical applications of control in the context of real systems in our surroundings. I implemented new teaching methods that allow students to directly apply the theory learned in class to real physical systems.

The curriculum was re-designed to incorporate a new co-requisite Process Control Laboratory (ME352).I split the class into groups of no more than 8 and meet weekly in the Mechatronics Laboratory (limiting the groups to 8 is constrained by the size of the Mechatronics Laboratory and amount of experimental rigs available but also has positive teaching outcomes since I am able to give students more individualized instruction). In these laboratories, students are exposed to practical applications using two process control (PROCON) educational rigs from Feedback, Inc. When I arrived at Cooper Union these PROCON test rigs were in disrepair and not being utilized in the curriculum. I re-commissioned the hardware in these test rigs, which closely reflects systems that students would see in industry, and completely re-designed the software interface and lab manual and assignments to better align with course theory. The first rig allows students to control the flow and level of water through a circuit and tank, while the second rig is a thermal system in which the temperature of two flows is regulated by controlling the flow rates through a heat exchanger. Using both the PROCON rigs, small student groups identify process variables in the physical systems and utilize industrial control equipment to implement the tuning methods learned in class.

The laboratory modules allow students to become familiar with the inherent complications of controlling physical systems, providing an important supplement to the knowledge acquired through lecture, analytical and computational modeling, and control simulations. For example, the thermal process rig exposes students to system lag, a facet of control systems that cannot be taught effectively through theory alone. Furthermore, the experimental rigs allow students to become familiar with equipment and procedures commonly encountered in industry. Later in the semester, students model DC Motor Trainers from National Instruments and then apply feedback control to control the speed and position of the DC motor. This allows them to progressively apply what they are learning and follow a system from modeling, to simulation, and finally feedback control.

Alongside these laboratories, it is important to show students how the experimental procedures are implemented to achieve real engineering goals in the field. Midway through the course, I take small groups of students on a tour of the HVAC mechanical rooms in 41 Cooper Square. Throughout these tours, the operation and control of the building's equipment is related to the concepts shown both theoretically in class and experimentally in the laboratory. The students' direct exposure to tangible applications of engineering theory provides a more thorough view of control systems and increases professional awareness.

During the tours, I also introduce students to a wide variety of innovative green features housed at 41 Cooper Square. These features include a cogeneration plant, chiller plant with water-side free cooling, air-side economizers, a rainwater collection system, and a state-of-the-art Building Management System (BMS). As part of my NSF Transforming Undergraduate Engineering Education (TUES) "Building Sustainability into Control Systems Courses" grant (DUE #1044830, $107,884) I developed online learning materials to supplement the HVAC and BMS tours. Students are assigned background reading material on the Engineering Faculty website (engfac.cooper.edu/melody/10) to read before the tours. These learning materials are available to the public and I have received numerous accolades and requests to use the materials. As of July 12, 2017, the online learning materials received <u>145,000 total visits and 124,000 unique visitor-days</u>! Below is an unsolicited email I received from Tom Hayes, Directorate of Facilities Management at the NASA Goddard Space Flight Center, regarding the Chiller background reading materials I posted:

> *"It's simply the clearest, easiest to understand industrial chiller explanation I've ever read, out of many. Well done. The diagrams are clear also. I wish more people could lay out the facts in such an organized fashion. Everybody's job would be easier."*

With funding from my NSF grant, a student researcher created a real-time PowerDashboard, on which students can see the building's power consumption real-time. I assign a writing assignment which is graded using an assessment rubric. I also customized and adopted the **S**tudent **A**ssessment of **L**earning **G**ains (SALG)[1] survey to assess student perceived learning gains and other affective measures. I presented five peer-reviewed ASME and ASEE conference publications and presented posters at four regional and national conferences related to the development of these new teaching methods.

Included in the portfolio are the following supplemental documents related to ME351 and ME352:

1. Three posters presented at regional and national conferences (refer to Posters section)
2. Five Engineering Education publications (refer to Publications section)
3. Student SALG course survey results
4. Online learning materials and feedback
5. Real-time Power Dashboard
6. Course syllabi
7. Sample Process Control (PROCON) laboratory assignment

Related Publications:

Baglione, M., "Building Sustainability into Control Systems: A New Facilities-Based and Hands-On Teaching Approach," 2015, 122nd ASEE Annual Conference Paper #13199, June 14-17, 2015, Seattle, WA.

Baglione, M., del Cerro, G., "Building Sustainability into Control Systems: Preliminary Assessment of a New Facilities-Based and Hands-On Teaching Approach," *Proc. of the 2014 ASEE Zone 1 Conference*, Apr. 3-5, Bridgeport, CT. *Nominated for Best Professional Paper Award.*

[1] The SALG instrument was developed in 1997 as part of National Science Foundation-funded consortia that developed and tested modular curricula and pedagogy for undergraduate courses. The SALG site is currently used by 7,769 instructors. Information on the development of the SALG, and on validity and reliability evidence of the approach can be found in:Seymour, E., Wiese, D., Hunter, A. &Daffinrud, S.M., 2000,"Creating a Better Mousetrap: On-line Student Assessment of their Learning Gains,"*Paper presentation at the National Meeting of the American Chemical Society*, San Francisco, CA.

Zielkowski, A., Baglione, M., Wootton, D., "Determining System Time Constant Through Experimental and Analytical Techniques," *Proc. of the 2014 ASEE Zone 1 Conference*, Apr. 3-5, Bridgeport, CT. *Nominated for Best Student Paper Award.*

Baglione, M., Caubel, J., "Developing Undergraduate Engineering Curriculum Material using the Heating, Ventilation, and Air Conditioning and Building Management Systems of a High Performance Academic Building," *Proc. of the 2012 ASME International Mechanical Engineering Congress and Exposition*, November 9-12, Houston, TX.

Baglione, M., "Incorporating Practical Laboratory Experiments to Reinforce Dynamic Systems and Control Concepts," *Proc. of the 2009 ASME International Mechanical Engineering Congress and Exposition*, November 13-19, 2009, Lake Buena Vista, FL, Vol. 7, pp. 391-395.

Conferences/Poster Sessions:

Baglione, M., "Building Sustainability into Control Systems: A New Facilities-Based and Hands-On Teaching Approach," 2015, 122nd ASEE Annual Conference NSF Grantees' Poster Session, June 14-17, 2015, Seattle, WA. Click here for link to poster.

DiStefano, T., "Reforming Engineering Education: An Experiential Approach to Control Systems Design and Building Sustainability," *2015 ASEE Northeast Section Conference Student Poster Abstract*, Apr. 30-May 2, 2015, Boston, MA. Abstract link. Click here for link to poster.

2013 NSF TUES/CCLI PI Conference, January 23-25, 2013, Washington, DC, Abstract and Poster Link

MECHANICAL VIBRATION (ME301)

In ME301 students learn free and forced vibration for single-degree-of-freedom and multiple-degree-of-freedom systems and are introduced to vibration suppression concepts. This course is primarily taught in the traditional chalkboard lecture mode with some PowerPoint used to illustrate real-world applications. I implemented two new components to this course –a vibration testing methods laboratory, which students perform concurrently in their Engineering Experimentation (ME360) course, and a team project – to supplement the theory with real-world, hands-on learning.

As part of the vibration testing methods laboratory, students design their own virtual instrument using National Instruments LabVIEW and work with industry standard piezoelectric accelerometers and data acquisition hardware. Students experimentally obtain the damping ratio and natural frequency of a cantilever beam and compare their experimental results to their theoretical hand calculations. Students are introduced to digital signal processing considerations and analyze their data in both the time and frequency domains.

Once students are familiar with vibration testing methods, students are assigned team projects, in which they approach an open-ended vibration problem. Students need to work together to formulate and propose a problem, collect data and/or develop a numerical or analytical model, and co-present and co-author a final presentation and technical report. I developed a set of proposal, presentation, and technical reporting guidelines and grading factors so students know what is expected of them. After grading the final deliverables, I give the students feedback as to where they can improve their technical and professional skills. During presentations students also assess their peers and give feedback by filling out forms with the presentation factors.

Included in the portfolio are the following supplemental documents related to ME301:

1. Example student projects
2. Student SALG course survey results
3. ABET course syllabus

ADVANCED MECHANICAL VIBRATION (ME401)

Advanced Mechanical Vibration (ME401) is a graduate-level course that introduces students to the field of structural dynamics and experimental modal analysis. The Advanced Mechanical Vibration course offered prior to my arrival covered purely analytical vibration methods. I developed this entirely new course out of a desire to combine advanced topics in both analytical and experimental dynamics and vibration. I teach this class using a combination of lectures and discussions using PowerPoint slides, by deriving analytical solutions on the chalkboard, and by dedicating a significant portion of the class time to laboratory assignments and course projects.

Approximately one-quarter of class time is dedicated to learning digital signal processing and data acquisition techniques. These skills are extremely useful in a number of different research and career paths, even those that do not involve vibration testing and structural dynamics. Class survey feedback indicates that the students feel they gain a tremendous amount in their ability to “conduct experiments and analyze and interpret data” (ABET outcome b) and “use modern skills, tools, and techniques necessary for engineering practice” (ABET outcome k).

Then students proceed to conduct experimental modal analysis on a simple cantilever beam such that they can verify their experimental results analytically to gain confidence in their testing methods before moving on to more complicated structures. The last few weeks of the class are spent working on projects where students select an open-ended vibration problem and conduct experimental modal analysis and analyze the dynamic properties of a structure for troubleshooting, simulation and prediction, optimization, and/or diagnostics and health monitoring. Since being elected Chair, I have not been able to offer this course, but I have offered it to interested students as an Independent Study.

Included in the portfolio are the following supplemental documents related to ME401:

1. ABET course syllabus
2. Sample student projects
3. Student SALG course survey results

INTERDISCIPLINARY ACOUSTICS, VIBRATION, AND NOISE CONTROL (EID260/EID160)

I developed and organized all new teaching materials for EID260 when I taught it in the Fall 2010 semester. I have not had space in my schedule to teach the course since then but have given the course as an independent study to eight students from all different departments (I plan to recommend an adjunct, who works in the acoustics field at ARUP to teach EID260 in Spring 2018). In order to maintain the interdisciplinary nature of the course and attract students from all three schools, I tried to maintain a balance between engineering analysis and broad practical application. This was the first class I taught with architecture students and it was exciting to have students from different schools interact and widen their perspectives. While the course requires some mathematical analysis, I made sure to teach it in a way that appropriate for all. I created PowerPoint slides to introduce course concepts. We also did calculations in class, held discussions, and spent time in the laboratory and in various site locations using sound analysis and data acquisition equipment.

I acquired a state-of-the-art Larson Davis sound level meter and several PCB Piezotronic and B&K measurement microphones, omnidirectional speakers for reverberation testing, and other acoustic instrumentation (much of which was donated or offered at a steep discount) to facilitate student projects and research into acoustics and noise control.

I created two laboratory exercises, in which students gain training in sound level meters and microphones and field work related to sound measurement. I also assign projects in which students approach real-world acoustics problems.

My independent study students have worked on a number of acoustics related projects, including analyzing the acoustics characteristics of spaces on campus and noise in the community. Students have characterized the acoustics of the anechoic chamber, various classrooms, the Kanbar Lab, Rose Auditorium and The Great Hall. Since 2014, I have involved my students on the Sounds of New York City (SONYC) project, a collaboration with the NYU Center for Urban Science + Progress, to evaluate the frequency response of low-cost, acoustic sensing devices for monitoring the urban sound environment. Over the summer of 2017, two students worked on developing a low-cost ambiosonic microphone in collaboration with the NYU Immersive Audio Group. In Spring 2017, independent study students have worked on an outreach project to analyze and recommend a low-cost auditorium acoustics treatment for a nearby New York public school, NEST+m.

Included in the portfolio are the following supplemental documents related to EID260:

1. Sample course projects
2. ABET course syllabus

SENIOR CAPSTONE DESIGN (ME393/394)

I serve as the course coordinator for Senior Capstone Design and have advised 36 Senior Capstone Design projects. Senior Capstone Design is the culmination of the students' experience at Cooper and an opportunity for our students to apply and hone their technical and professional skills on a year-long design project. Given this, I started using the Senior Design experience to more consistently and systematically assess our students' attainment of ABET a-k outcomes. As such, I developed a senior design assessment rubric, grading criteria, and an evaluation spreadsheet so that students know the course expectations and faculty can more consistently evaluate their work. Moreover, the ME faculty can use the results of this assessment and evaluation process to look for opportunities to improve the ME curricular content and delivery methods. Previously senior design class time was devoted to guest speakers. While we still have occasional guest speakers, I have reworked the senior design class to include a number of workshops, in which students are actively reflecting on the design process and honing their professional skills. I have worked closely with the School of Engineering Writing Fellows and co-created a number of writing workshops. The writing workshops are supplemented with handouts, well-defined student learning outcomes, performance indicators, a grading rubric, and critiques of work products. I also created Informed Design, Problem Framing, Background Research, Poster Perfect Design, and Mock Poster Session workshops. We also spend class time critiquing students' presentations, posters and technical reports. Student assessment and surveys indicate these new workshops help the students improve their communication skills and ability to communicate with a specific audience and purpose in mind.

Another goal of mine has been to promote service-learning or industry-sponsored projects so students get an opportunity to work on user-oriented, real-world projects and interact with clients with a real need. Additional benefits include increasing Cooper Union's visibility with prospective employers and in the community and helping further Peter Cooper's mission of industrial innovation and civic service. Last year, students collaborated with the Brooklyn Transition Center, a public high school for students with special needs on the development of a mobile market stand to supplement their bike maintenance and greenmarket programs. This year, I helped facilitate a project where students design a Wheelchair in collaboration with Cooper alum, Nick Wong (ME'14) from Upcycles, and Achilles International, an organization that helps people with disabilities participate in running events. Students have also worked on the design of an Interactive Light Studio to help deaf students visualize sound. Other past projects include Formula SAE-related design projects, myoelectric-controlled prostheses and creating automated fault diagnosis tools to identify building energy saving opportunities.

Included in the portfolio are the following supplemental documents related to ME394:

1. Sample Grading Criterion
2. Example Final ME394 Posters and Reports
3. Student SALG Surveys