Redesigning the First-Year Experience for Engineering Undergraduates

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Abstract - The J.B. Speed School of Engineering at the University of Louisville is in the process of restructuring its courses that introduce freshman students to the engineering profession. A two-course sequence (Engineering Methods, Tools, and Practice I and II) will be inaugurated in Fall 2016 and taken by all first-year engineering students. The Paul-Elder Critical Thinking Framework will be taught and used throughout the sequence. Engineering Methods, Tools, and Practice I will focus on fundamental engineering knowledge and skills, including: 1) engineering professionalism (ethics, culture, and risk), 2) basic computational and programming skills, 3) graphical, oral and written communication, 4) problem solving, 5) design analysis, 6) teamwork (emphasizing diversity and inclusion), and 7) project management. Engineering Methods, Tools, and Practice II will involve a team design project that focuses on the application and enhancement of skills acquired in Engineering Methods, Tools, and Practice I. In Engineering Methods, Tools, and Practice II, students will have a choice between projects that are “build” or “model and simulate”. Engineering Methods, Tools, and Practice II will conclude with demonstrations and presentations of the team projects and delivery of a final report.

INTRODUCTION

The J.B. Speed School of Engineering (SSoE) at the University of Louisville (UofL) is redesigning its first-year introduction to engineering program to support the school’s effort to have a common first year for engineering students and provide them with a more realistic view of the engineering experience via UofL’s new Institute for Product Realization’s maker community. SSoE’s desire to restructure this program was largely motivated by the fact that nearly one third of retained engineering students changed majors by the end of their first year and had to take additional courses that delayed their normal progression to graduation; thus striving to reach a common first year would be beneficial to our students. Additional motivations for restructuring include the desire to improve the potential for success in subsequent courses, and to provide a more substantial first-year exposure to realistic aspects of engineering design and the engineering profession.

To achieve these goals, a school-wide committee (with representation from all engineering departments) was created to evaluate SSoE’s current instruction in introduction to engineering, graphics, and introductory programming. The committee was charged to make a recommendation for replacing current stand-alone courses in these areas with an integrated two-course sequence in the first year that introduces all new SSoE students to the practice of engineering and provides an introduction to essential methods, tools, and skills for success in engineering. The committee reviewed similar courses offered at engineering colleges with common first-year programs and developed a set of desired student learning outcomes. The result was a two-course sequence: Engineering Methods, Tools, & Practice I (ENGR 110) and Engineering Methods, Tools, & Practice II (ENGR 111). This sequence will commence in Fall 2016 and will be required for all first-year SSoE students.

ENGR 110 will focus on skills development in seven topic areas: 1) engineering professionalism (ethics, culture, and risk), 2) basic computational and programming skills, 3) graphical, oral and written communication, 4) problem solving, 5) design analysis, 6) teamwork (emphasizing diversity and inclusion), and 7) project management. ENGR 111 will necessitate demonstration and integration of skills via completion of a team design project. In concert with UofL’s Quality Enhancement Plan [1], students will be taught the Paul-Elder (PE) Critical Thinking Framework [2] – [7] and will use it throughout the two-course sequence.

A team of faculty in the Engineering Fundamentals Department at SSoE are currently working to develop the new course sequence. The team meets biweekly to discuss progress in different aspects of the course (e.g. development of online instructional materials for programming and graphics or determination of budget/supplies necessary for design projects). Development of various course aspects are occurring simultaneously and faculty team meetings are key to integrating course concepts into the second semester design projects. Following is a description of course aspects developed to date.

ENGINEERING METHODS, TOOLS & PRACTICE I
ENGR 110 is intended to provide first-year engineering students with an introduction to critical thinking, essential methods, tools and skills for success in engineering. To encourage student awareness of ‘real-world’ issues, lectures and activities for this course will be framed around the U.S. National Academy of Engineers Grand Challenges for Engineering [8]. The PE critical thinking framework will be taught in the early stages of this course, and will be put into practice via written assignments and a hands-on, field-based exercise. Pedagogical details pertaining to each of the seven skill topics established for this course are given in the following sub-sections.

I. Engineering Professionalism

Students will learn meaningful definitions of engineering ethics, diversity, culture and risk and will be made aware of their significance in the moral practice of engineering. Discussed topics will include the National Society of Professional Engineers Code of Ethics [9] and the Engineer’s Creed [10]. Additionally, students will learn the process for becoming a licensed Professional Engineer in Kentucky.

Students will be tasked with thinking critically on two individual writing assignments – one where they will reflect on which of the Grand Challenges they might choose to pursue professionally, and one in which they are instructed to analyze the ethical issues surrounding a specific Grand Challenge.

II. Basic Computational and Programming Skills

Students will be introduced to the topic of computer programming by learning some basic programming skills in Python. Students will use Python to write and debug simple programs that solve basic engineering problems. The programming section of this course will have the students learning input/output, variable processing, decision structures, loop structures, and functions. These concepts form the basics of most programming languages. The delivery of this material will include: videos that help students install Python on their machine and introduce, explain, and demonstrate each topic and the use of MyProgrammingLab [11] for assignments. MyProgrammingLab is an interactive online module that allows students to respond to posed problems by typing in code, then evaluates the code for correctness. This provides the students with real-time feedback on their understanding of the programming concepts.

Students will also learn essential computational capabilities of Microsoft Excel. This will be accomplished using the MyITLab [12] interactive online module. This interactive module also allows the students to answer questions by manipulating a simulated Excel spreadsheet in a virtual environment. This environment evaluates their commands and actions related to the questions being asked.

The system provides real-time feedback on their understanding of the Excel concepts.

III. Communication

Students will begin their education in graphical communication by learning to describe two dimensional and three dimensional visualization problems using projection theory, visualization methods, and pictorial sketching. Graphics content will be delivered via video lectures and demonstrations, with pertinent text material attached to each lesson.

Proper guidelines and procedures for written and oral communication will be discussed and augmented by a final report and presentation on the design analysis assignment (sub-section V). Student teams will also create a short video presentations that describe one of the Grand Challenges that will be viewed by the class.

IV. Problem Solving

In addition to the built-in problem solving components of programming and Excel exercises, another course activity applicable to problem solving will provide student exposure to another fundamental engineering concept: vectors. Utilizing a compass, altimeter, and tape measure, student teams will calculate vectors that map different paths between specific campus locations. Students will then compare and assess calculated paths and reflect critically on the results (e.g. assessment of why position and return vectors don’t sum to zero). This activity will provide another opportunity for students to use the PE framework in a more applied, project-based manner.

V. Design Analysis

Students will be educated on the various stages of the design process. Student teams will demonstrate an understanding of this process by developing a conceptual design that advances one of the Grand Challenges. Students will learn tools to assist them in making design decisions such as objective trees and decision matrices. Completion of the design will conclude with a report and presentation near the end of the semester. Report requirements will involve communicating problem statements and methodology in developing their designs, as well as an ethics reflection specific to their design.

VI. Teamwork

The various team-based activities and assignments discussed in the preceding sub-sections will assist students in developing the ability to collaborate as team members in small groups, learning how to manage group activities, and dealing with conflict between team members. Students will be instructed in effective team practices, roles, and
suggestions for resolving team issues [13]. The first class activity pertaining to teamwork development will involve formed teams working together in a ‘survival scenario’ game [14]. Individual teaming skills will be assessed via peer evaluations from fellow teammates.

VII. Project Management

In addition to effective team practices, students will learn tools and techniques for effective management of team projects such as identifying tasks, team member roles/responsibilities, and timelines through development of Gantt charts.

ENGINEERING METHODS, TOOLS & PRACTICE II

ENGR 111 is being structured to help students begin to develop professional habits that will benefit them both while at UofL and as a practicing engineer, and builds upon the foundation formed in ENGR 110 by requiring students to complete a team design project. The projects will: answer an open-ended question or perform a tangible task that relates to real-world engineering experiences or applications, necessitate integration of skills acquired in the first course, require application of critical thinking paradigms, and further enhance teaming skills. In an effort to promote a work ethic appropriate for the engineering profession, the course is being organized in a manner that requires approximately 20 hours of productive work per team member for their team project. ENGR 111 will also introduce students to 3D-printing and the Arduinos electronics platform.

The first three weeks of this course will consist of project- relevant laboratory exercises and videos that prepare teams for the design project. Sample subjects during this time will include lab safety training, 3D software and printing, Arduinos basics, etc. Student teams will be allowed to choose among two types of design projects – a “build” project or a “model and simulate” project. Preliminary efforts have been focused on development of the build project, thus details pertaining to the model and simulate project are currently limited.

The current guidelines for the first build project will ask students to build and design a small-scale power plant. More specifically, students will be tasked with creating a system that generates power using an alternative energy source (i.e. no burning of fossil fuels) and use the Arduinos platform to distribute and store the energy. The build project can be broken down into four key elements:

• Constructing: For the initial course sequence, students will be tasked with assembling a windmill. (In subsequent semesters, students may be given a choice of assembly between a windmill, a solar Stirling engine, or a hydroelectric turbine). Student teams will be provided with step-by-step instructions on how to construct this element of the project.

• Designing: Student teams will demonstrate their understanding of the design process by designing the interface between the constructed element and a DC Motor. In order for this element to remain as open-ended as possible, it is likely that the only constraints given are a minimum speed ratio between the input shaft (constructed element) and output shaft (DC motor) and a minimum rotation speed for the output shaft – in addition to the requirement that they design a housing for the interface that is “serviceable”. Teams will use 3-D parametric modeling software to create basic components and assemblies, and parts will be created using large-scale production printers at UofL’s Rapid Prototyping Center [15]. Teams will be allowed no more than three production runs during the semester.

• Programming: Students will write and de-bug programs that distribute and store the generated energy within their electronics platform. Upon demonstration, the system will light an LED (to confirm actual power generation) while simultaneously charging a battery bank. After a fixed amount of time, renewable resource unavailability will be simulated; thus the team-created logic will need to be capable of powering the LED from the stored energy in the batteries. Students may also write a program that measures the speed of the input shaft.

• Reporting: Throughout the semester, students will be responsible for communicating technical information pertaining to their project (e.g. design, design alternatives, troubleshooting, and/or product selection). A Gantt chart & proposal will be required early in the semester, followed by periodic progress reports through the remainder of the semester.

ENGR 111 will conclude with demonstrations and presentations of team projects and delivery of a final report. Final report requirements will include a Gantt chart (Project Management), detailed discussion of the design process, engineering drawings, and a discussion of any ethical implications realized during design & implementation.

CONCLUSIONS AND FUTURE DIRECTIONS

Collaborative efforts among several SSoE faculty are currently underway to develop a new two-course Engineering Methods, Tools, and Practice sequence for all first-year students that incorporates and integrates content from previous Introduction to Engineering, Introductory Programming, and Graphical Communications courses. Initial efforts have focused on development of course topics and delivery in the first-semester course and development of a comprehensive “build” design project in the second semester.

Future efforts will focus on the second-semester design project course – primarily detailed development of the “model and simulate” project as an alternative to the “build” project. Additionally, introductory content (related to 3D CAD software and Arduinos, for example) will be developed. The first-semester course will be revised as needed to ensure delivery of content and skills necessary for the second-semester design focus. The Engineering
Fundamentals team will continue to meet biweekly as needed until the course launches in Fall 2016. Additionally, future efforts will be directed at assessment of student learning outcomes and evaluation of overall course effectiveness (with the expectation that future improvements will be necessary).

REFERENCES
[1] QEP: http://louisville.edu/ideastoaction/about/accreditation

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