First-year Redesign: LabVIEW, myRIO, EML, and More

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***Abstract* - Over the past year, faculty at Baylor implemented a new curriculum in a pilot course for first-year engineering students. The curriculum had four main objectives: encourage students to persist in engineering, foster self-motivation and curiosity, develop a fundamental set of knowledge and skills, and see the "big picture" of engineering design. Important characteristics of the new curriculum were: the use of a variety of hardware and software tools, including LabVIEW, myRIO, SolidWorks, and a Makerbot 3-D printer; an increased number of hands-on labs and projects; a focus on connecting concepts to other courses (math, science, and engineering courses); and a multi-part project that involved reverse engineering, 3-D modeling, material and sustainability considerations, redesign for a target customer group, prototyping, and presentation. Part of the motivation for this new curriculum was to promote "entrepreneurially minded learning" (EML), which aims to foster a mindset of curiosity, making connections, and creating value. Another motivation was to provide students with the tools they need to acquire internships after their freshman year. In this paper, the authors explain the details of the curriculum, feedback from students, some quantitative data, and lessons learned by the faculty.**

Index Terms - freshman, first-year, curriculum, LabVIEW, myRIO, entrepreneurially minded learning, EML.

BACKGROUND

At Baylor, all first-year engineering students take two, three-credit-hour introductory courses. The main objectives of these courses have been to provide students with a perspective on the field of engineering and a set of knowledge and skills that they will need later, including some experience with the design process. For the past several years, the first course focused on introducing the field of engineering by covering a broad range of topics, including problem solving, units, design, ethics, Excel, circuits, statics, and energy. The second course focused on math and programming, including complex numbers, linear algebra, MATLAB, and Mathcad.

Incoming engineering students enroll as Pre-engineering majors and are required to qualify before declaring one of three degree-granting majors (Electrical & Computer, Mechanical, or General Engineering). Details have been previously published [1]. One of the qualifying requirements is that students earn a grade of B or higher in each of the freshmen engineering courses. Hence, another purpose of these courses is to serve as the "gateway" to upper-division courses. Practically, this means that these courses must deliver a sufficient level of rigor to provide students with a preview of the work that is required to complete an engineering degree.

Additionally, incoming students must take a zero-credit-hour, six-week "student success" course, which covers topics, including academic policies and resources, communication with professors, study strategies, time management, and professional development. Because these are covered in an auxiliary course, they are not the focus of this paper. Details have been previously published [2].

PURPOSE OF REDESIGN

While the first-year engineering courses have accomplished their objectives, several of the instructors felt that the courses could be improved and offer more to students. Faculty at the University of Illinois at Urbana-Champaign established the Illinois Foundry for Tech Vision and Leadership (iFoundry), which allowed them to form pilot programs with a metaphor borrowed from industry, "…build it small, work out the kinks, and then scale it up [3]." The authors chose to mirror this iFoundry metaphor and offered a pilot of a redesigned curriculum in 2016-2017 to a single section of the freshman engineering course sequence.

The authors were also influenced by the Kern Entrepreneurial Engineering Network (KEEN), which has identified three elements of an "entrepreneurial mindset": curiosity, connections, and creating value [4]. Students with this mindset are motivated to learn new ideas, relate them to concepts they previously learned, and put that body of knowledge to work in developing solutions that provide value, beyond simple feasibility, to others. In preparation for this course redesign, the second author attended a KEEN workshop on Innovation Curriculum with Entrepreneurial Mindset (ICE) [5].

The pilot course's four major goals were that students would:

- Self-identify as engineers and take responsibility for attaining their degree.
- Develop self-motivation and curiosity.
- Acquire a set of fundamental knowledge and skills.

- Begin to understand the relationships among the stakeholders involved in the practice of engineering (i.e., customers, manufacturers, distributors, marketers, etc.)

The first goal encompasses the students' development of the identity of being an engineer through projects and the design process. Also included under this goal are typical first-year topics, such as introducing the different engineering disciplines and employment opportunities, explaining the learning process, and empowering students to be successful. The last ties back to the zero-hour course mentioned earlier.

The second goal encourages students' motivation and desire to learn. Professors focus on getting students to ask probing questions and to connect topics to other courses. For example, students may be more motivated to learn calculus or differential equations if they experience hands-on examples of how these subjects are applied in engineering.

The third goal comprises technical topics (e.g., units, circuits, or statics), "soft" skills (e.g., problem solving and writing), and specific tools (e.g., Excel, LabView, MATLAB, or SolidWorks).

The final goal revolves around people, teamwork, and communication. Students experience how engineers interact with other engineers, with manufacturing, with marketing, and with customers. All of these relationships converge in the design of a product, and an engineer needs to be able to interact appropriately with each of these stakeholders.

IMPLEMENTATION

Within these broad goals, more specific objectives were defined. Lectures, assignments, and projects were developed to meet these objectives. The following is a simplified outline for the year:

- First semester
  - Design
  - Communication
  - Units, Excel, and math models
  - Circuits & LabVIEW (interleaved)
  - SolidWorks & engineering materials
- Second semester
  - Linear algebra
  - Complex numbers
  - MATLAB basics & programming
  - Mathcad
  - 3-D printing
  - Alarm clock prototype & presentation
  - Machines Lab (i.e., gears, linkages, motors)
  - MATLAB mini-project

Electrical circuits and programming in LabVIEW were taught concurrently, using the National Instruments myRIO platform. Each student purchased a device, which was used both in class for lab-style exercises and outside of class for projects. This section of the course was taught as a mixture of traditional lecture and discovery learning. Students were given weekly assignments and were expected to augment their learning using available tutorials or through experimentation. The lectures were purposely designed so that they did not cover everything that was needed to complete assignments.

Modules Developed at ICE Workshop

Four integrated modules were developed, based on lessons learned at the ICE Workshop and are presented here as examples of the types of modules that were developed for this course. Figures 1 through 6 were taken directly from student work.

I. Reverse Engineering

The study of existing consumer products by testing their functionality and then dissecting them to study their internal design and subsystems is a valuable exercise because it provides insights into a wide variety of decisions made by the design, engineering, and manufacturing personnel who brought this product successfully to market.

FIGURE 1
COMMON CONSUMER PRODUCT, A DIGITAL ALARM CLOCK, THAT WAS USED IN FOUR MODULES OF THE REDESIGNED COURSE.

This exercise was assigned in the first week of the fall semester and was intended to help incoming freshmen self-identify as engineers. Students were assigned to teams of two and were supplied with a common consumer product, a digital alarm clock (*See Figure* 1). First, students tested all the functions performed by the product. Second, the students dissected the clock and identified subsystems in the clock. Third, students assessed the clock for possible design flaws and potential improvements. Each team submitted a formal report with required components. The objectives of this exercise were that students would: function as a team; test the functionality of a common consumer product; examine the product by dissecting the device; generate a bill of materials for the device; analyze the design of the device; identify multiple sub-systems within the device; assess the device for possible design flaws; and write a technical report on the product, its subsystems, and any identified design flaws. The analysis and dissection of the digital clock took one class period. The written report was worked on outside class and due one week later. Students were provided feedback on the report and given an additional week to revise and resubmit the report.

II. CAD Model and Eco Audit

In the second of four modules using the digital alarm clock, students analyzed the materials that comprised the previously disassembled digital alarm clock, performed an Eco Audit (CES EduPack 2016, Granta Design, UK) to examine the environmental impact of this consumer product (*See Figure 2*), and developed a 3D CAD model of the clock case (*See Figure 3*) using SolidWorks (Dassault Systems, Waltham, MA).

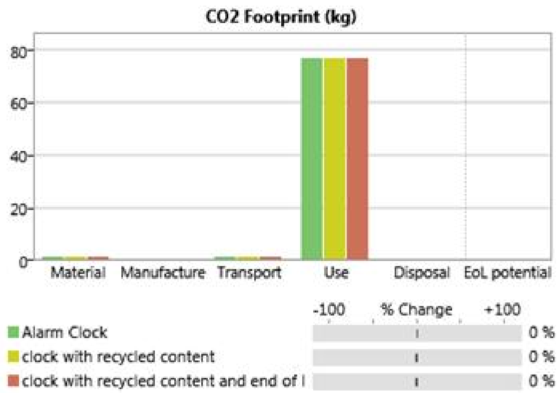

FIGURE 2
EXAMPLE OF THE CARBON FOOTPRINT GRAPHIC COMPARING DIFFERENT LEVELS OF RECYCLING AND THEIR EFFECT ON THE CARBON FOOTPRINT OF THE DIGITAL ALARM CLOCK. BECAUSE MOST OF THE ENERGY USED IS DURING THE USE PHASE OF THE PRODUCT LIFE CYCLE, THERE WERE NO BENEFITS TO EITHER MANUFACTURING THE CLOCK WITH RECYCLED MATERIAL OR TO RECYCLING CLOCK MATERIALS AT THE END OF ITS LIFE.

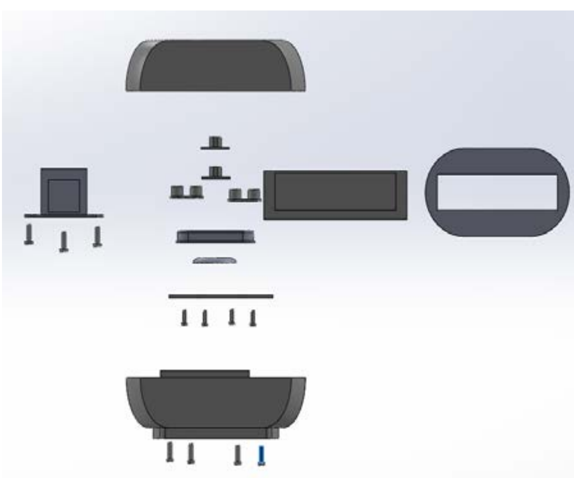

FIGURE 3
EXAMPLE OF A SOLIDWORKS 3D CAD MODEL SUBMITTED BY STUDENTS.

This exercise was assigned near the end of the fall semester after students had completed SolidWorks tutorials. Students remained in the same teams assigned for the Reverse Engineering exercise. The objectives of this exercise were that students would: function as a team; examine the environmental impact of a common consumer product; assess the impact on the carbon footprint of the product by the use of recycling at varying points in the product's life cycle; provide a brief technical analysis of the carbon footprint of the product and the assessment of different methods for reduction of the environmental impact; and generate a 3D CAD model of a physical object using dimensions measured from the object itself. The Eco Audit analysis took one class period. The CAD model and written report were worked on outside class and due two weeks later.

III. Customer Interviews and Redesign

The third of four modules was assigned at the beginning of the spring semester. Students were assigned to different teams than for the first two modules. Teams were asked to select a target customer group (e.g. young boys, trendy urbanites, elderly adults), gather information about their needs, redesign an existing product to meet those needs (*See Figure 4*), and assess the impact that the redesign would have on other stakeholders (e.g. materials sourcing, manufacturing, marketing, distribution).

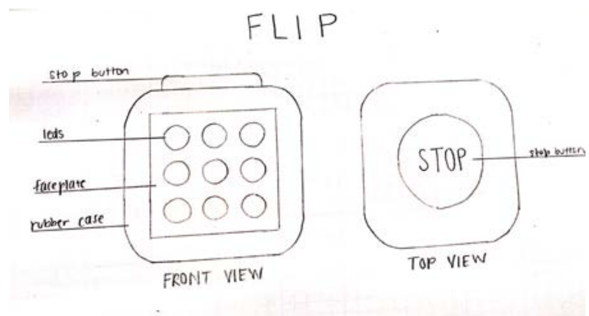

FIGURE 4
EXAMPLE OF HAND DRAWN DESIGN FOR A CLOCK INTENDED FOR CHILDREN WITH AUTISM.

The objectives of this exercise were that students would: function as a team; asked questions of a target customer group; design a product to meet desired objectives; consider who the stakeholders for a particular product were; and consider how changes to the product would impact those stakeholders. Interviews were conducted, and the report was prepared outside class over a 3-week period. The deliverable was a technical report detailing target market research and interview results, three preliminary redesign ideas, a selection matrix, the selected design, and an assessment of the stakeholder impact.

IV. Prototype

The final module of the digital alarm clock project was assigned after spring break. Students remained in the same teams assigned for the redesign exercise and were asked to develop two prototypes of their redesigned clock. There were three deliverables. First, each team converted their clock design into a SolidWorks model of the clock case. The case was printed (*See Figure 5*) on a MakerBot Replicator+ 3D printer (MakerBot Industries, Brooklyn, NY). Second, each team utilized their myRio units, the myRio Starter kit, and LabVIEW (National Instruments, Austin, TX) to develop a functional model of their redesigned clock. Third, each team presented a formal presentation of their alarm clock prototypes in class.

FIGURE 5
EXAMPLE OF A 3D-PRINTED CLOCK CASE. THIS CLOCK WAS DESIGNED AS A CHILDREN'S CLOCK. THE CLASS NICKNAMED THIS DESIGN THE DISCO BALL CLOCK.

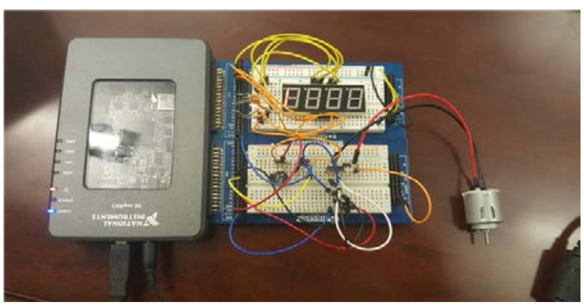

FIGURE 6
EXAMPLE OF A FUNCTIONAL PROTOTYPE THAT WAS PROGRAMMED IN LABVIEW AND CONSTRUCTED ON A BREADBOARD USING THE NI MYRIO.

The objectives of this exercise were that students would: function as a team; generate a redesigned clock case in SolidWorks; convert the clock case into an STL file; convert the clock case into a Makerbot file using Makerbot Print; generate a 3D printed prototype of their alarm clock case; design the circuitry/logic and user interface for their alarm clock; develop a functional prototype of this logic and interface using the MyRio, MyRio Starter Kit, and LabView; and present their alarm clock prototype and demonstrate its functionality to the class. The professors, graduate assistant, and all students in the class provided evaluation for project and presentation quality. Students also provided peer assessment of their team member.

STUDENT FEEDBACK

Alarm Clock Modules

I. Reverse Engineering

The students were very enthusiastic about the reverse engineering exercise in the first week of the fall semester. This module achieved the goal of developing a connection to the engineering discipline and to encourage incoming freshmen to immediately self-identify as engineers.

II. CAD Model and Eco Audit

There were some complaints from students about the lack of "sage-on-the-stage" lectures on SolidWorks. This was a bit surprising to both authors because of the stress that had been placed on the students' need to be self-motivated to develop their skills and knowledge. This most likely resulted due to two factors. First, the students were still in their first semester and in the process of transitioning from high schools in which the teachers taught them everything they were expected to know to college-level expectations. Second, there were inevitable comparisons drawn between the pilot section and the other sections that were being taught using the old course plan. This issue will not occur in the future because all sections of the course will be taught according to the new course model.

III. Customer Interviews and Redesign

Some teams initially developed possible redesign ideas prior to performing target market interviews. Students expressed a high level of surprise when their ideas were not embraced by the individuals who were being interviewed. There was some confusion about what was meant by the term "stakeholders". This will receive more attention in the future.

IV. Prototype

LabVIEW proved to be a difficult tool to use for the development of the functional prototype. There were many problems with the use of the myRio. It was prohibitively expensive at more than $300/unit with the academic discount. There were many technical issues and glitches related to getting the units to function on all students' laptop computers. The plan for the future is to use Arduinos and have the students program them in Matlab (or change the project).

Student surveys

At the end of each semester, anonymous surveys were sent to all students in EGR1301 – Introduction to Engineering (Fall semester) and EGR1302 – Introduction to Engineering Analysis (Spring semester). This allowed comparison of student perceptions between the pilot section and the non-pilot sections. Figure 7 shows the results of the survey for four specific skills. With the exception of the "Asking questions" skill, the students in the pilot course scored modestly higher on "3D visualization" and "Teamwork". The second-semester pilot group displayed a considerably higher score for "Writing."

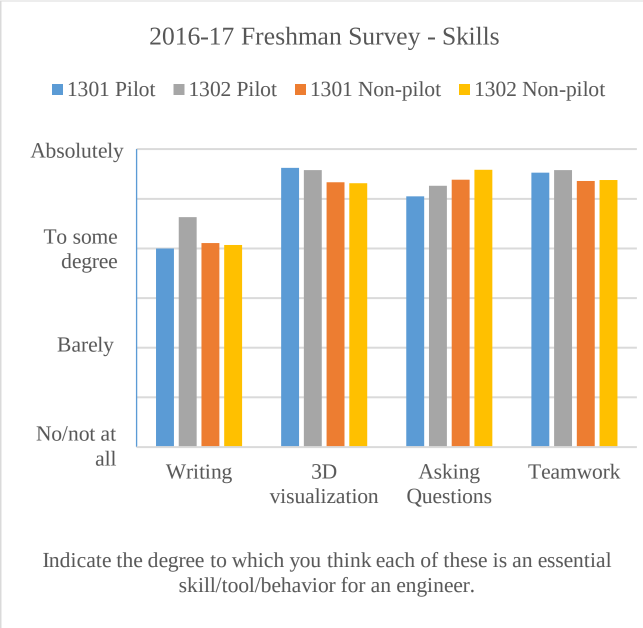

FIGURE 7
SURVEY RESULTS FOR SELECTED SKILLS.

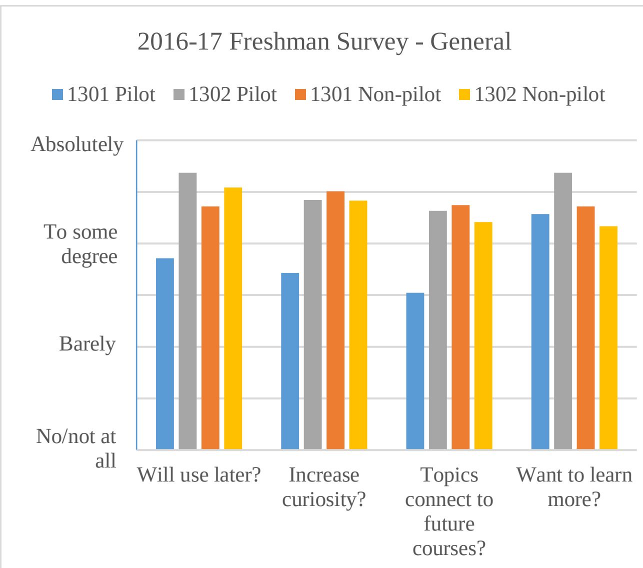

FIGURE 8
SURVEY RESULTS FOR SELECTED GENERAL QUESTIONS.

Figure 8 shows the results of four general questions. Feedback from the pilot class at the end of the first semester was quite negative. Many of the students were frustrated with the class, and these results show that. By the end of the second semester, the pilot section students were much more satisfied. Ratings for "Will use later" and "Want to learn more" demonstrate improved student satisfaction. Interestingly, the second-semester pilot students did not rate "Increased curiosity" any higher than the non-pilot classes. This seems in direct conflict with their rating of "Want to learn more". Thus, it is suspected that the pilot students may have interpreted the question differently than the authors intended.

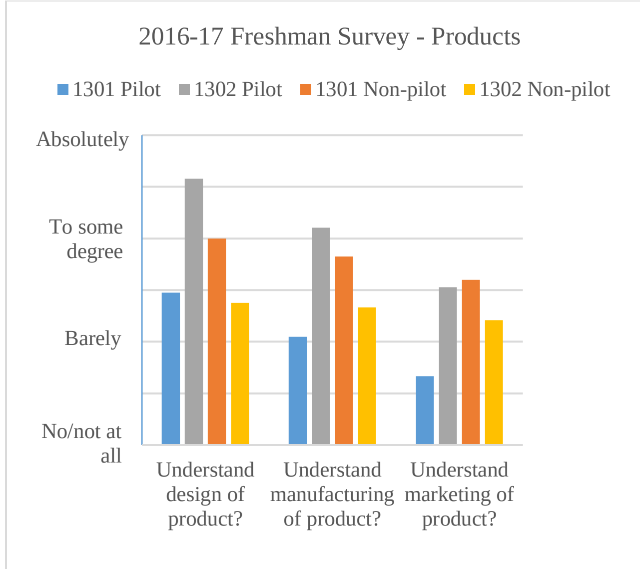

FIGURE 9
SURVEY RESULTS RELATED TO CONSUMER PRODUCT DEVELOPMENT

Figure 9 presents the students' answers to questions regarding design, manufacturing, and marketing of products. Not surprisingly, the second-semester pilot students rated themselves considerably higher on design and somewhat higher on manufacturing.

In addition to the survey, the pilot group participated in an in-class discussion and feedback session at the end of the second semester. Students wrote positive and negative aspects about the first semester on sticky notes, placed them on a whiteboard, and then grouped them topically. The process was repeated for the second semester. Much of this feedback was specific to these courses, but applicable generalizations will be included in the next section.

DISCUSSION & CONCLUSIONS

Lessons Learned

A number of observations can be drawn from the authors' experiences, student surveys, feedback session, and informal conversations with students:

- Students really enjoy CAD modeling and 3-D printing.
- Insufficient preparation, faculty support, and teaching assistant support led to disorganization in the class. The curriculum needs to be well-developed and executed with sufficient personnel support. More preparation should have been done in the summer before the class.
- Students in a pilot class compare themselves to those in the other classes and complain when they perceive that they are working harder than their friends in the other sections. The chief issue here is that students do not always know what is good for them. For example, they typically did not like writing, but it is an extremely important skill that is repeatedly stressed by our industrial boards.
- Students, first-year students at Baylor in particular, demonstrate a negative bias toward topics that they

perceive as unnecessary. For example, a relatively large population of pilot students planned to pursue a Mechanical Engineering degree and did not perceive the value of spending a significant amount of time on programming and electrical circuits. Faculty understand that topics and problems do not exist in silos, but first-year students have not yet learned that lesson.

- National Instrument's myRIO device was difficult to use. Many students had trouble installing or communicating with it. Even though the myRio connects via USB, it installs as a network device. This means that the device is subject to firewall settings and other network issues. The authors could have made better use of their contacts at NI, asking for help in resolving these kinds of issues.
- National Instrument's LabView was not the best software tool selection for programming the functional prototype of the digital alarm clock.

Future Plans

Faculty who are teaching a pilot course need to be willing to have their class compared to the other classes and for their student evaluations to possibly decline, especially if the pilot is perceived as more difficult than the comparison class. More attention needs to be given to providing a more balanced curriculum (i.e., Electrical and Computer vs Mechanical topics) and helping students understand the importance of all topics. The selection of the myRio was expensive and led to frustrating technical issues, some of which were not ever fully resolved. In the future, the selection of Arduino over the myRio will hopefully provide a less expensive, more user-friendly device for future design projects. The less expensive technology purchase will allow for the selection of additional textbooks, such as a technical writing text or a more comprehensive MATLAB text.

Despite the challenges and frustrations of the pilot course, the faculty recognize the value of learning from failure. At the conclusion of the in-class discussion and feedback section, the students spoke of their growing realization in the closing weeks of the spring semester that they had benefitted greatly from choosing to enroll in the more challenging pilot course. The students appreciated their improved communication skills and the feedback provided by the faculty. They recognized the value of the tools and technologies that they learned and that their classmates had not. For example, one female student attended a national conference for a professional society and acquired an internship at a large, well-known company, due in large part to her knowledge of LabVIEW. The student reported that a large component of the interview was spent answering questions that the interviewer had about the content of the pilot course. The authors found the interviewer's interest in our pilot course particularly rewarding because this interest mirrored the recommendations of our industry boards to move technical content earlier in the curriculum to make our students competitive for internships earlier in their academic career. The freshmen engineering faculty met to discuss the results of the pilot course, and the consensus was to deploy this redesigned course to all sections for the upcoming academic year.

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