Combining Projects and Informational Sessions to Create a Comprehensive Introduction to the Department

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***Abstract*— The Industrial and Enterprise Systems Engineering department at the University of Illinois at Urbana-Champaign has five major research areas: data analytics; decision and control systems; design and manufacturing; financial engineering; and operations research. During the summer of 2015, faculty and graduate students from each of the last four areas designed mini-projects and assignments to cover the research areas of the department in a required first-year course. The goal of the designed course was to provide a comprehensive overview of the department and an engaging experience for first-year students. Project-based learning and Kolb's cycle for experiential learning were used to inform the structure of the course. Pre-surveys and post-surveys were administered to gather feedback from students in the course. On the surveys, students reported an increase in understanding of each of the research areas and a positive experience in the course.**

Keywords—project-based learning; first-year experience; general engineering; industrial engineering

I. Introduction

Specialized first-year experiences are gaining popularity in engineering. Some common goals for these first-year experiences are improving professional skills [1], [2], functioning on multidisciplinary teams [3], and increasing motivation [3], [4]. There are many successful examples of these first-year courses. In the Industrial and Enterprise Systems Engineering (ISE) department at the University of Illinois at Urbana-Champaign, we had similar goals for our first-year course, and we wanted to increase the understanding of research areas and enthusiasm within the department.

The ISE department has two undergraduate majors: industrial engineering (IE) and general engineering (GE). Within ISE there are five major research areas: data analytics; decision and control systems; design and manufacturing; financial engineering; and operations research. Faculty and graduate students from each of the last four areas designed mini-projects for students to complete during the course. Data analytics was excluded due to time and the lack of approachable hands-on activities that could be developed within the time-frame of this course. We used a project-based learning model as the basis for the redesign of the course because of the numerous successful examples in the literature. Project-based learning has shown to increase retention and student satisfaction [5]. Additionally, project-based learning is an approach for introducing real engineering problems and concepts as well as integration into the university [6]. After completing a first-year project-based course students reported an increase in motivation and confirmation of their choice to become an engineer [7].

II. Background

Both project-based learning and experiential learning have had positive outcomes for learning. Both are also popular instructional methods in first-year programs in engineering. We reviewed other project-based, first-year programs prior to redesigning our first-year course.

A. Experiential learning

Since [8] introduced the experiential learning model in 1978, hundreds of studies have been published across all disciplines including engineering. In his model, there are four modes of experiential learning: (1) concrete experience, (2) reflective observation, (3) abstract conceptualization, and (4) active experimentation. For a *concrete experience*, a student should have an open mind and be immersed in the situation. Then, for *reflective observation*, they should reflect on the experience from multiple perspectives. Next, in *abstract conceptualization*, they should turn their observations into concepts and theories. Finally, for *active experimentation*, they should use the new theories to solve problems or make decisions. Students may enter the cycle at any point, but need to experience all four modes.

B. Project-based learning

Project-based learning is a set of tasks leading to a final product [9]. The final product can be in many forms including a design, a computer simulation, or a device [10]. Project-based learning differs from problem-based learning. Problem based learning usually centers around an open-ended problem or question [9]. A seven-step curriculum model was defined for both project-based and problem-based learning courses

[11]. The seven steps are objectives and outcomes; types of problems, projects, and lectures; students' learning; progression, size, and duration; academic staff and facilitation; space and organization; and assessment and evaluation [11].

There are multiple examples of project-based or problem-based first-year courses, such as engineering design [2], design and professional skills [1], heat transfer [4], and electrical engineering [3]. All of these examples focus on one project or example for the duration of the course. However, [3] warns that confusion can arise if the one multi-disciplinary problem is used in one course for multiple majors. Because first-year students might not appreciate the interdisciplinary nature of real-world problems or how the multi-disciplinary projects relate to their major, they may lose interest in the project [3].

Because the nature of our department is interdisciplinary and our students have a variety of interests we chose to use multiple smaller projects that each highlight a different area. Introductory lectures were provided before each project to explain the motivation and connection to ISE. This paper provides an initial analysis of the change in students' perception of their knowledge of departmental research areas and their reaction to the projects and overall course.

III. PURPOSE

A team of ISE faculty and graduate students redesigned the first year course to align with the research areas. The redesign was prompted by student feedback, which indicated that undergraduate students did not have a clear understanding of the ISE department and its research areas. Therefore, the emphasis of the topics to be covered in the new version of the course were the major research areas of the department. Additionally, we wanted to make sure that each student understanding the expectations and future career options of their major.

This redesigned aligned with other curriculum changes in the department, the curriculum changes included increasing the credits from 0 to 1. Therefore, the format of the course needed to be changed from the primarily seminar format of the previous version of the course. We taught the course in the redesigned format during the fall semester of 2015.

IV. METHODS

Students in the course completed a pre-survey after the first class and a post-survey after the last class. In addition, copies of all homework assignments were kept for further analysis. All of the assignments and surveys were submitted in Blackboard, the course management system. We received institutional review board approval to collect survey data and assignments for analysis in this course.

A. *Context of the course*

GE 100 is required for all first-year students majoring in IE or GE. It is an 11-week, 1-credit, course that meets once a week for 50 minutes during the fall semester. There were approximately 60 students enrolled in the only section of the course. One faculty member was assigned as the instructor of the course. In addition, a graduate teaching assistant and three undergraduate learning assistants were assigned to the course.

Each area includes an introductory lecture, in-class project, and homework assignment. All of the mini-projects created a connection to experiences that first-year students would understand. For example, the decision and control systems mini-project used a line-following robot. In the introductory lecture, a video of Amazon's warehouse robots was shown to explain an application of a line following robot. The students worked in groups of three to complete each mini-project. However, students submitted their own homework assignment after each mini-project. The mini-projects were completed in seven of classes. The other classes in the course consist of introductory material, guest lectures, and concluding material. Table 1 summarizes the schedule for each session of the of the 11-week course. The learning objectives for GE 100 were as follows:

1. Introduce students to the range of technical topics that can be studied within the ISE department.
2. Help students develop their own vision for their educational trajectory.
3. Help students experience the connection between fundamental math and science topics and real-world engineering problems.

Table 1. GE 100 course schedule.

Week	Topic
1	Introductory lecture
2	Control systems lecture and tutorial
3	Control systems project
4	ISE Advising
5	Operations research tutorial
6	Operations research project
7	Examples of ISE senior capstone projects
8	Design and manufacturing tutorial
9	Design and manufacturing project
10	Financial engineering tutorial and project
11	Conclusion and wrap-up

B. *Project descriptions*

Each project was designed to be completed in one 50-minute class session. For the control systems project, each group was provided a Zumo robot [12] and an Arduino [13]. One student from each group brought a computer to edit the code for the Zumo robot based on the provided instructions. The Codebender website [14] was used to edit, compile, deploy the code for the robot. In the first part of the project, each team was provided a code shell and they added an open loop control to drive their robot. Then, they implemented a closed loop control law with three different gains. Each team had a track to test their each gain on the robot before proceeding. Each team demonstrated their working robot to the teaching assistant or one of the undergraduate learning assistant before leaving class on the day of the project.

The design and manufacturing project consisted of a software simulation in MATLAB and a verification test. In the simulation, the student teams adjusted parameters to manually identify the near optimal dimensions for pouring from a can. They then verified their answers on a reconfigurable testbed. Overall, the activity emphasized the combination of simulations based on accurate physical models and experimental testing to realize a successful product.

For operations research project, the students were provided with a JAVA-based GUI platform where a graph with several interconnected nodes and connections. Each connection had an associated metric. The students were told that the graph illustrated possible routes between two cities and they were asked to identify the shortest path, and then compare their answers to the optimal solution. Through a series of assignments, the students were lead through the branch and bound algorithm that determines the shortest path.

Due to time constraints, financial engineering applications were discussed in lecture, but the students did not complete a simulation or project related to financial engineering.

C. Homework assignments

After each project, students completed an individual homework assignment about their experience with the project. The assignments were meant to check for understanding of the main concepts covered in the tutorial and the project as well as one guided reflection question. Kolb's cycle of experiential learning [8] was used as a guide for developing assignments.

The questions from control systems assignment were as follows:

1. List at least five examples of control systems you've experienced.
2. Explain the difference between open-loop and closed-loop control.
3. Why is it important for some control systems to have feedback?
4. Describe the differences in the robot's ability to follow the line when you changed the code from

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a. speedDifference = error;
b. speedDifference = error * 2;
c. speedDifference = error / 4;
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   Why do you think the robot responded in that way?

Student individually completed similar observation and reflection questions after each project. Students submitted all of the assignments in Blackboard, the course management system.

D. Assessment of redesign

Students in the course completed a pre-survey after the first class and a post-survey after the last class. In addition, copies of all homework assignments were kept for further analysis. Students completed both surveys in Blackboard, as well. Some questions were the same on both the pre-survey and post-survey. The following questions were in both surveys:

1. What is your major?
2. In one sentence, describe industrial engineering.
3. In one sentence, describe general engineering.
4. What type of career do you plan to pursue after graduation? Please be as specific as possible.
5. How would you rate your knowledge about the following:
    a. Control systems
    b. Operations research
    c. Design and manufacturing
    d. Financial engineering

For each of the areas in question 5 above, the students were provided with a Likert scale: nothing at all, a little, a moderate amount, a lot, and a great deal. On the beginning survey, we collected data about why students were interested in majoring in engineering and what courses they completed prior to enrolling in GE 100. On the end of semester survey, we also collected demographic data and other feedback about GE 100.

Survey question 5 and other questions on the post-survey were included to assess student's perception of learning about the department (objective 1). Additional questions on the post-survey were included to understand the student's educational and career aspirations (objective 2). Finally, the homework assignments were designed to assess the students understanding of the research area and the connection to real-world applications (objective 3).

V. Results

We have conducted an initial analysis of the pre-survey and post-survey conducted in GE 100. Overall, the students had generally positive feedback about the course and reported a positive experience in the course. First, we looked at the demographics of the students enrolled in the course. Then, we analyzed the students' self-rating of their knowledge in each of the areas of the department.

A. Demographics

We started by analyzing the demographics of the students enrolled in the course based on the survey responses. Since the demographic survey questions were not required, there were some omitted responses. The summary of the demographics is included in Table 2. The demographics were similar to previous first-year classes in the department.

Table 2. Demographics of GE 100.

Category	Value	Count
Major	General Engineering	27
	Industrial Engineering	27
	Undecided/Other	4
Gender	Male	30
	Female	23
First Language	English	38
	Other	16
Student Status	Domestic	39
	International	15

B. Improved understanding

The students reported their understanding of each topic area based on the provided Likert scale. Fig. 1 – Fig 4 contain histograms of the students' self-rating on the beginning and ending survey. Additionally, statistics of each rating are included in Table 3. We also tested each self-rating of knowledge for normality using the Shapiro test [15]. Because the data did not appear to be normal, we chose the Wilcoxon-

Rank Sum test to compare the beginning and ending survey responses. The p-value provided in Table 3 is from the Wilcoxon-Rank Sum test. Based on an $\alpha = 0.05$, students reported an increase in knowledge in each research area covered in the course.

C. *Feedback on projects*

Most students reported that their favorite project was the control systems project, see Fig. 5. One common reason reported for that liking the control systems project the most was that it was hands-on. Most students reported that their least favorite project was financial engineering. The reasons provided for liking financial engineering the least were confusion and not being interested in the topic.

Table 3. Statistics of students' self-rating of knowledge before and after taking GE 100.

	Before			After			*p-value*
Area	***n***	***M***	***SD***	***n***	***M***	***SD***	
Control systems	52	2.21	1.05	56	3.09	0.75	1.000
Operations Research	52	1.96	0.91	56	3.00	0.87	1.000
Design & manufacturing	51	2.67	1.14	56	3.09	0.77	0.997
Financial engineering	52	2.19	1.03	55	2.67	1.02	0.994

VI. Conclusions and Future Work

The projects added to this course were well received. Based on comments it appears that students prefer hands-on projects like the robot used in the control systems project were preferred over the simulations used in the other projects. The knowledge students' perception of their knowledge in each research of the department improved as a result of the course.

Future work included analysis of the assignments as another assessment of understanding of topics in the course and department. Additionally, other survey questions like summarizing each major in the department in one sentence will be scored on the before and after surveys to evaluate a change in understanding of the department. Additional analysis of survey data is also planned.

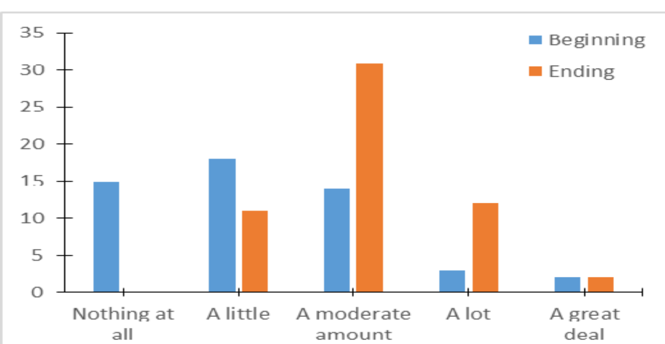

Fig. 1. Self-rating of knowledge about control systems.

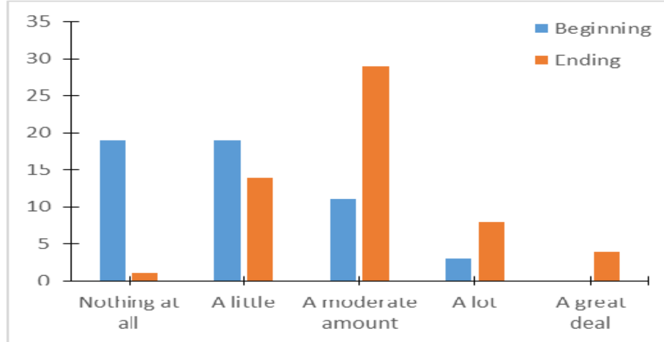

Fig. 2. Self-rating of knowledge about operations research.

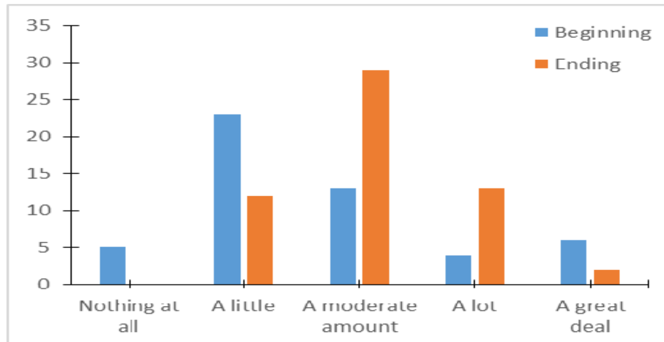

Fig. 3. Self-rating of knowledge about design and manufacturing.

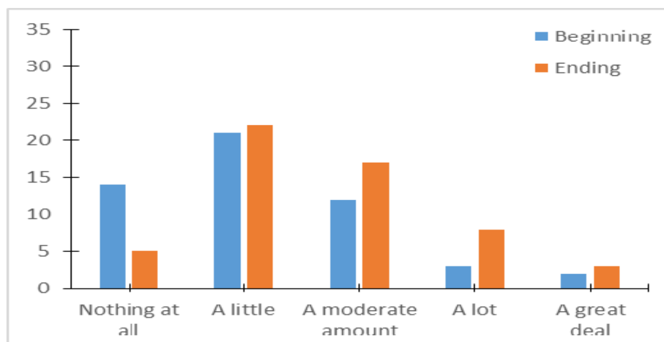

Fig. 4. Self-rating of knowledge about financial engineering.

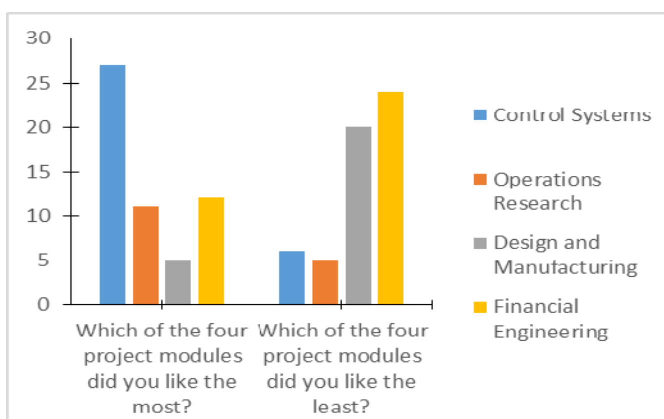

Fig. 5. Student rank of projects in GE 100.

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