Interdisciplinary Freshman Experience

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Abstract

This paper summarizes a cooperative effort undertaken by the Aeronautical, Electrical, and Computer Engineering Departments at Embry-Riddle Aeronautical University that led to the development of a team-taught interdisciplinary engineering course offered to incoming freshmen. The authors discuss the inception of the project, the development of the course content, and the lessons learned from the first year of teaching the course as a prototype using a select subset of incoming engineering freshmen.

In the past, each engineering department at Embry-Riddle University conducted its own introduction to engineering class. The College decided about a year ago that our graduates saw themselves as engineers in their specific discipline and not as engineers on an interdisciplinary team. In order to begin the change of philosophy, a team was put together from each engineering department to create a freshman course that would emphasize the interdisciplinary nature of current engineering practice. The instructors share lecture and grading responsibility, and attempt to integrate material relative to their own areas of expertise into an interdisciplinary design experience.

Introduction

The purpose of this paper is to provide insight into the development of an Introduction to Engineering course at Embry-Riddle Aeronautical University (ERAU) in Prescott, Arizona. This course was created as a part of a ‘common core’ freshmen program, and was intended to provide students with a multi-disciplinary experience branching the aerospace engineering, electrical engineering, computer engineering, and computer science fields of study. As such, the course was team-taught by faculty drawn from each of the various disciplines. Each instructor was tasked with developing lecture and laboratory content which would allow students to develop cross-discipline engineering design skills.

This paper begins by describing the course goals and objectives as envisioned by the instructor team. A description of the organization of the course and the sequencing of the subject matter follows, along with a discussion of how lecture and laboratory time was utilized in ensuring that the goals and objectives were realized. This will be followed by a summary of the lessons learned by the instructors in implementing the class material, and a final discussion of the plan to scale the course to include all incoming engineering freshmen.
Course Goals and Objectives

Before describing the goals and objectives envisioned for this particular course, it is useful to define the terms ‘goal’ and ‘objective’ in the context of this paper. The course goals describe the knowledge that the students are expected to retain from the course and take with them into the engineering field. The course objectives define the skills that are to be mastered in the completion of the course requirements, leading the students to garner the knowledge necessary to attain the course goals.

The reason for moving to a common freshmen core and the role of this multi-disciplinary freshman design course is two fold. First, in their senior capstone course, the students are encouraged to participate in a multi-disciplinary design project but are sometimes reluctant due to not knowing students in other engineering majors and not being aware of what skills seniors from other disciplines can bring to the team. It is hoped that by starting all engineering students in common courses will encourage early interactions which will enable better team performance later. The second goal is to allow for some mobility for students in choosing between the different majors. Students who are attracted to ERAU are highly motivated by a desire to work in the aerospace industry and, as a result, the aerospace engineering program is much larger then the other engineering majors. By showing the multi-disciplinary nature of aerospace design, the expectation is that some students will recognize their ability to specialize in disciplines like electrical engineering or computer science, to which they may have a greater affinity, and still find a rewarding career in aerospace.

The primary goal of this course is to teach basic design skills within the various disciplines, while allowing the students to have fun in the process. This goal is aimed at retaining students within the engineering field by exposing them to some of the more enjoyable aspects of the profession. In order to foster this environment, the course was focused on hands-on creative design projects culminating in competitions between teams, with final grades depending upon team performance. Developing team skills, therefore, was an important goal, as was the promotion of project management abilities. The development of written and oral communication proficiency was also highly emphasized. Additional goals included providing a historical perspective of engineering and instilling engineering ethical values through the discussion of lessons learned and industry related case studies.

To attain the goal of fostering an enjoyable design experience, student teams were required to design, construct and program Lego Mindstorms robots as a primary course objective. These robotic systems allow students to program a central control unit which responds to inputs from touch and light sensors, as well as infrared signals. To further develop engineering design proficiency, all students were required to demonstrate basic computer aided design skills utilizing Solidworks software. The use of this software allowed for an easy interface with a Z Corporation 3-D Printer for rapid prototyping of their designs. In order to promote written communication skills, design teams were obligated to submit reports describing their concepts in accordance with the ERAU College of Engineering Style Manual – the college standard for technical reports which was introduced to the students in this course and will be covered in detail in a later course. It was also mandatory that all teams prepare and deliver Preliminary and
Critical Design Review presentations in order to promote their oral communication skills. The preparation for these reviews also fostered project planning and management abilities, as well as an understanding of the mechanics and control of ground and flight vehicles.

### Lecture Topics

ERAU operates on a semester schedule and this course is worth 2 credit hours – 1 hour of lecture and 2 hours of lab per week. The lecture topics can be roughly split into two categories. In the first category were the following lectures:

- Introduction to the Engineering Profession and Disciplines
- History of Engineering
- The Engineering Design Process and Time Management
- Introduction to Technical Report Writing
- Teamwork
- Engineering Ethics

These topics are of course important to all engineering projects and are generally covered in all introductory engineering courses.

The second category of lecture topics concentrated on supporting the specific design projects. In particular, the lectures concentrated on the air vehicle project. The topics were:

- Computer Aided Design (CAD) (supplemented by two laboratory sessions)
- Introduction to Statics and Dynamics
- Lighter-Than-Air Vehicle (LTAV) Weight and Buoyancy
- LTAV Stability and Control Concepts
- Basic Feedback Control Theory
- Into. to Aeropropulsion/Propellers
- Into. to Electric Motors and Pulse Width Modulation (PWM)

These topics will have to be adapted in future semesters to fit the chosen design projects. It may also be useful to add some formal discussion on the issues of ground vehicle design. While the Mindstorms® systems are geared towards ground vehicle design and are largely intuitive or self-paced learning, some issues such as the trade-off between motor torque and speed and feedback control concepts might have been beneficial.

### Laboratory Projects

Attaining the primary goal of providing the students with an interesting, involving, interdisciplinary laboratory experience proved to be quite a challenge. Since the students would be from aerospace engineering, electrical engineering, computer engineering, and computer science, the quantity and topics of lab assignments was extensively debated. The primary conflicts were between experiments that were sufficiently broad to capture the students' diverse interests, complicated enough to require design, and yet could be conducted by students with no engineering experience. It was decided that the best solution was to have two robotic projects plus a few labs at the start of the semester that directly supported the projects. The first project was a semi-autonomous land vehicle that could navigate the two-dimensional course depicted in Figure 1 with a typical student design shown in Figure 2. This project allowed the students to become proficient with the Mindstorms® programming interface and provided experience with
the unpredictability of the real-world, particularly the impact of battery charge and variation in traction due to the lab carpet.

Figure 1: Sketch of Course for Ground Vehicle Competition

![Sketch of Course for Ground Vehicle Competition](image1)

Figure 2: Photo of Typical Ground Vehicle

![Photo of Typical Ground Vehicle](image2)

The second project was a LTAV that could change altitude and heading to navigate a three-dimensional course, as depicted in Figure 3. This project provided even greater experience with the vagaries of the real-world and allowed the students to sharpen their understanding of
aerodynamics and aeropropulsion. Both projects were announced at the start of the course in order to gain and retain the attention of the students from the various disciplines. Since the students had no appreciable engineering experience, the projects sounded simple enough. The students imagined many embellishments, were not intimidated, yet realized that design would be required to accomplish the goal. The need for design was further heightened by both projects culminating in competitions between teams, with the winning teams receiving the best grades. The students realized that a good design could provide the needed edge on the competition.

![Figure 3: Sketch of LTAV Competition Course](image)

Figure 4 shows two teams flying their designs during the competition. The team on the right is using light signals to give feedback to their LTAV while the team on the left is using infrared communication signals. One member on each team was required to hold a restraining tether line to prevent the vehicles from accidentally rising above a controllable altitude.

Software is critical to the projects, so the lab sequence began with program design. The proprietary Mindstorms® programming interface is a click-and-drag, graphical interface that is very reminiscent of working with building-blocks, consequently Nassi-Shneiderman Charts were introduced as the software design tool. The second support lab topic was Computer Aided Design and use of the three-dimensional printer. For these labs, the students were guided in designing an initial undercarriage for the blimp.
The students were encouraged to continue the use of CAD and 3D realization beyond these initial support labs, usually by illustrating ways that the concepts they were learning in lectures could be applied to improve their projects. The CAD software is available in the engineering computer labs, which allowed the students to work on their designs outside of lab time. This freed their assigned lab time for experimentation with and refinement of their project software and their design implementations. The open experimentation fostered discovery and innovation, for example, crude but effective ways for estimating the efficiency of propellers they had designed. The 3D printer allowed the students to experience first-hand the relationship between volume and weight. This led them to discover that while simple solids are quick to design, they are a waste of time and materials where weight is a major design restraint.

The development of team skills during lab was also fostered, including project management abilities, by requiring that each team create and present both Preliminary and Critical Design Reviews (PDR and CDR) for their LTAV projects. These reviews were held during lab time and were presented to the course instructors in confidential briefings, as would be done in industry.

In the ways described above, the laboratory work addressed the course goals of encouraging active participation in engineering design experiences, instilling a sense of appreciation for the creative aspects of engineering, providing hands-on design and construction opportunities, engaging the students in discussions relating to the interdisciplinary aspects of modern engineering, and developing written and oral communication skills through lab reports and oral presentations. The labs contributed to the course objectives of producing students who can design, construct, and program Mindstorm® robots, possess basic CAD skills, prepare and deliver oral presentations in Preliminary Design Reviews and Critical Design Reviews, work
productively on a design team, prepare written lab reports according to the ERAU College of Engineering Style Manual, understand the basics of project planning and management, and understand the fundamentals of the mechanics and control of lighter-than-air vehicles.

Results

We enrolled 25 students in the first class. Enthusiasm was high all through the semester. The final grades divided between A’s and B’s as might be expected from the select student population. The end-of-course student evaluations were generally favorable. Table 1 shows the results of the surveys completed by 20 of the 25 enrolled students.

<table>
<thead>
<tr>
<th>My instructor</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods and materials helped me learn</td>
<td>55%</td>
<td>25%</td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examinations/assignments reflect the materials covered in class</td>
<td>30%</td>
<td>40%</td>
<td>10%</td>
<td>15%</td>
<td>5%</td>
</tr>
<tr>
<td>Challenged me to think critically and to express myself effectively</td>
<td>70%</td>
<td>20%</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shows interest in and respect for me as a student</td>
<td>65%</td>
<td>20%</td>
<td>15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shows enthusiasm for and interest in the subject matter.</td>
<td>75%</td>
<td>15%</td>
<td>10%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>While it is difficult to compare instructors, especially in different subject areas, how would you rate this instructor on a comparative basis with other instructors?</td>
<td>60%</td>
<td>20%</td>
<td>15%</td>
<td>5%</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: End of Course Student Survey EGR 101 – 20 students responding

Since the class was team taught, as was the intent to demonstrate the interdisciplinary nature of engineering, it was hard for the students to develop an attachment to the course instructor. The nature of the standard end of course questions administered to all classes reflects one instructor per class. Still it is possible to draw conclusions from the survey. These students did not like the lack of homework and detailed instructions such as “do the following things and you will receive an A in the course.” The students were uneasy due to the relatively unstructured nature of the engineering design problems. But we wanted them to experience this before their later classes so their concern is not unexpected.

Typical favorable comments included:
  - Awesome course taught by great instructors.
  - The Legos are excellent facilitators for education on the engineering method (i.e. Legos are fun).
  - The fact that there were five of them helped a lot. It’s like learning from a five-headed monster.
  - Cool and fun class.

Typical negative comments included:
- This course was too difficult for a 101 level course. It was fun but required work that wasn’t expected until upper-level courses.
- Need more assignments for grade padding.
- I would have liked a better set syllabus that would let me know what was going on for each class. I feel I would have performed better and procrastinated less.

We also ran discipline specific courses for the aeronautical engineering students and a combined course for the electrical and computer engineering students. The combined EE/CE/ class is called CEC 100, and was taught by a member of the EGR 101 team. The CEC 100 course used the materials from the Infinity Project (http://www.infinity-project.org/). An instructor who had many years of experience in the course taught the AE class, called AE 101. The results from similar end of course surveys are provided in Tables 2 and 3.

<table>
<thead>
<tr>
<th>My instructor</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods and materials helped me learn</td>
<td>36.4%</td>
<td>50.0%</td>
<td>4.5%</td>
<td>9.1%</td>
<td></td>
</tr>
<tr>
<td>Examinations/assignments reflect the materials covered in class</td>
<td>63.6%</td>
<td>18.2%</td>
<td>18.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Challenged me to think critically and to express myself effectively.</td>
<td>27.3%</td>
<td>45.5%</td>
<td>22.7%</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>Shows interest in and respect for me as a student.</td>
<td>40.9%</td>
<td>50.0%</td>
<td>4.5%</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>Shows enthusiasm for and interest in the subject matter.</td>
<td>63.6%</td>
<td>27.3%</td>
<td>4.5%</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>While it is difficult to compare instructors, especially in different subject areas, how would you rate this instructor on a comparative basis with other instructors?</td>
<td>36.4%</td>
<td>50.0%</td>
<td>13.6%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: End of Course Student Survey CEC 100 - 22 students responding

<table>
<thead>
<tr>
<th>My instructor</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methods and materials helped me learn</td>
<td>33.4%</td>
<td>48.6%</td>
<td>10.7%</td>
<td>5.9%</td>
<td>1.9%</td>
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<tr>
<td>Examinations/assignments reflect the materials covered in class</td>
<td>58.1%</td>
<td>28.7%</td>
<td>13.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Challenged me to think critically and to express myself effectively.</td>
<td>27.5%</td>
<td>46.4%</td>
<td>21.3%</td>
<td>4.7%</td>
<td></td>
</tr>
<tr>
<td>Shows interest in and respect for me as a student.</td>
<td>49.1%</td>
<td>36.6%</td>
<td>11.9%</td>
<td>1.9%</td>
<td></td>
</tr>
<tr>
<td>Shows enthusiasm for and interest in the subject matter.</td>
<td>51.3%</td>
<td>31.0%</td>
<td>11.7%</td>
<td>4.8%</td>
<td>1.8%</td>
</tr>
<tr>
<td>While it is difficult to compare instructors, especially in different subject areas, how would you rate this instructor on a comparative basis with other instructors?</td>
<td>32.1%</td>
<td>38.2%</td>
<td>28.5%</td>
<td>1.8%</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: End of Course Student Survey AE101- 84 students responding
Most markings are similar and demonstrate that, in the students’ opinion, there is little to distinguish team teaching from a single instructor. Where there is a difference, the students in EGR 101 gave higher scores for “Methods and materials helped me learn” than did the CEC 100 and AE 101 students. Both courses have a strong lab content and the difference in the ratings is attributed to the design strength of the EGR 101 projects.

In the area of “Challenged me to think critically and to express myself effectively,” the EGR 101 class thought they were more challenged than the CEC 100/AE 101 students. This reflects the emphasis on communications in the PRD and CDR and the challenge of the design problems.

Lessons Learned and Scaling

While all the students and faculty involved had an enjoyable time, there were a number of lessons learned while running this prototype class which can be used to improve the course when it is offered to the entire freshman class in Fall 2005. A few of these lessons follow:

- Need to clarify expectations especially when the size of the class is increased.
- Many of these students were focused on achieving a final grade and were uncomfortable with the team/competition based grading system.
- Need to make the robotic car game more deterministic. There were too many variables that the students couldn’t control in their design and they found that frustrating.
- Not everyone will like the course regardless of how much fun we think it is.
- It is hard for students to appreciate what they are learning until after they get to see it applied in other courses. The seniors looking at what the freshmen were doing could appreciate it and wondered why they didn’t get this course.

Some of these lessons will aide in improving the next offering of the course. Some of this semester’s students will also be available to assist the course in the future which will greatly assist in the scaling of this course to the full freshman class and in providing more guidance to the design teams.

Bibliography

1. The Infinity Project, http://www.infinity-project.org/

Biographical Information

CHUCK CONE, PH.D.
Associate professor and head of the Electrical and Computer Engineering Departments at ERAU, Prescott. Worked as an electrical engineer for the U.S. Air Force and McDonnell-Douglas Corporation before joining the faculty at ERAU. Interests are in control theory and system integration.

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Currently an Assistant Professor of Aerospace Engineering where he teaches structural analysis, computer aided design, and aircraft detail design courses. He has 21 years of industry experience with McDonnell Douglas (now Boeing) and Northrop Grumman Corporation where he specialized in structural fatigue loading and served as manager of F-5/T-38 Engineering.

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Associate Professor of Electrical Engineering specializing in DSP and power electronics. He worked in the industrial robotics industry before joining the faculty at ERAU. He specializes in motor controllers and charge controllers and holds a patent for an AC motor controller.