Aerospace-Focused Multidisciplinary Project-Based Introductory Engineering Course

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Abstract – Introduction to Engineering (EGR 101) is a multidisciplinary, project-based, two-semester-hour course for first-time students in all the engineering disciplines at the Daytona Beach campus of Embry-Riddle Aeronautical University (ERAU–DB). The goals of EGR 101 are to introduce students to the multidisciplinary nature of engineering practice in the aerospace fields, to motivate students to succeed in engineering at ERAU–DB, and to facilitate students' development as engineers. EGR 101 incorporates and emphasizes interrelated multidisciplinary projects performed in teams. The aerospace-focused projects involve designing a launch system, parts of an imaging satellite, and an aircraft. The projects emphasize the systems integration intrinsic to multidisciplinary design. Additional course features include role-playing ethics investigations; an emphasis on professional development, resume building, and internships; implicit learning communities; and course delivery through a combination of twice-weekly section meetings with weekly assemblies. This paper describes the development, delivery, and assessment of EGR 101.

Keywords: Freshman, aerospace, multidisciplinary, team, design

INTRODUCTION

The College of Engineering (COE) at the Daytona Beach campus of Embry-Riddle Aeronautical University (ERAU–DB) offers undergraduate degrees in aerospace engineering (AE), civil engineering (CIV), computer engineering (CE), computer science (CS), electrical engineering (EE), mechanical engineering (ME), and software engineering (SE). During the 2003–2004 academic year, the programs adopted a common first-year including two new engineering courses: Introduction to Computing for Engineers (EGR 115), and Introduction to Engineering (EGR 101). This paper describes the development, delivery, and assessment of EGR 101.

Since the Embry-Riddle mission is to be the leading university with an aerospace-aviation focus, not only AE, but all degree programs in the COE have some form of aerospace flavor: CIV deals with transportation systems and the design and construction of airports; CE, embedded systems and unmanned aerial vehicles (UAVs), CS and SE, real-time, embedded, safety-critical systems; EE, communications and systems engineering; and ME, high-performance vehicles. Due both to the obvious fit of the AE program with the university mission and to the recognition it has

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received in recent years, the pool of first-time students in the COE is primarily in the AE program: Of the 450 or so students entering the college each fall, about 85% are in the AE program, with the remainder distributed among the other programs (Table I). One role for EGR 101, then, is to introduce all COE first-time students to the other engineering disciplines offered at ERAU–DB and to make it easier for students to transfer among those programs without losing academic credit; i.e., to facilitate transfers to the smaller programs. There was, however, an additional consideration that the introduction of EGR 101 should do no harm, in terms either of student preparedness or on the impact to degree programs: Students in each degree program should be as well or better prepared to pursue that degree as before, and the degree programs, especially the smaller programs, should show no adverse effect in enrollment due to the change.

Table I. EGR 101, fall 2004 and fall 2005, according to degree program, by percentage.

Degree Program	% of Students in Fall 2004	% of Students in Fall 2005
Aerospace Engineering (AE)	86.3	84.9
Computer Engineering (CE)	3.8	1.3
Civil Engineering (CIV)	2.8	2.0
Electrical Engineering (EE)	0.0	1.3
Mechanical Engineering (ME)	0.0	2.0
Software Engineering (SE)	2.8	1.3
Undeclared Engineering (UN)	1.9	7.2

In summer 2004, a working group of COE faculty (the authors) that included at least one representative of each of the COE departments convened to share and to integrate ideas and concepts into the EGR 101 outline. The group developed a course with a set of multidisciplinary aerospace-related design projects—the design of an imaging satellite, an aircraft system to transport the satellite from factory to launch site, and a launch vehicle system to put the satellite into orbit—as its primary activities, with additional activities supporting ethical behavior, professional development, and awareness of engineering practice across all the disciplines in the aerospace field.

This paper describes the goals, delivery, and assessment of EGR 101; the paper is organized as follows: The following section describes the goals of the EGR 101 course. The next section describes EGR 101 content and delivery, and the final section after that initial assessment of EGR 101 and anticipated changes to EGR 101 delivery. While the focus here is admittedly specific to the aerospace-focused ERAU programs—there is no explicit or implicit comparison with integrated first-year programs such as advocated by the NSF-sponsored coalitions of the 1990s [1], or with first-two-year programs such as the Unified Engineering sequence of MIT's Department of Aeronautics and Astronautics [2]—the approach hopefully has value in institutions with more diverse engineering programs.

EGR 101 GOALS

EGR 101 replaced introductory courses previously required by the degree programs: AE 101, Introduction to Aerospace Engineering; CEC 101, Introduction to Computer Engineering; CIV 101, Topics in Civil Engineering; and CS 100, Introduction to Computing. Each course provided an overview of the field and degree program, with the intent of motivating first-time students as well as clarifying the appropriateness of their career choices. It was important to retain enough degree specific material from each of the engineering disciplines at ERAU without overwhelming the first year students.

Simultaneous with the introduction of EGR 101, College Success (UNIV 101) was reintroduced into COE programs' curricula, to be offered by educational specialists associated with the campus First Year Program. Liaison with those specialists was established to sort out which course would cover what content, with some college success topics related to engineering careers retained in EGR 101. Since the UNIV 101 education specialists would be advising first-time engineering students, two-way communication channels were established so that student problems could be addressed.

The developed learning objectives of EGR 101 are for first-time engineering students to:

- Participate in, write up, and present team-based multidisciplinary design projects;
- Explore the engineering disciplines offered at Embry-Riddle and see how they fit together in the aerospace industry;
- Practice engineering ethics;
- Become aware of resources that facilitate success in an undergraduate engineering program, including professional organizations and networking with upper-division students; and
- Develop early-career goals, build a resume, and begin the employment-finding process, fully aware of the utility of co-ops and internships for early-career success.

EGR 101 DELIVERY

EGR 101 is a two-semester hour course with twice-weekly section meetings during the first eleven weeks of the academic semester. EGR 101 students also meet in assembly during many of those weeks. The course completes early to allow students to focus on end-of-term requirements of other courses; during the fall semester, it finished before Thanksgiving break. Current ERAU–DB COE enrollments of 400–450 first-time students each fall require 14 or 15 sections of 30 students each. Faculty members teach sections, assisted by an upper-division student in one of the engineering programs. Incoming students are pre-registered into EGR 101 sections without regard to degree; however, in order to build learning communities, students who are placed in a particular section of EGR 101 are also placed together in sections of math and physics and other courses when possible. Spring and summer enrollments are much smaller, and only one or two sections of EGR 101, without assemblies and profession-awareness activities, are offered; this paper only describes EGR 101 as presented in the fall semester.

There are three broad components to EGR 101 delivery: Section meetings (2 hours per week), all-hands assemblies (1 hour per week), and profession-awareness activities (three one-hour activities spread through the semester).

Section Meetings

Learning modules covered in section include development of teaming skills, team-performed multidisciplinary design projects, an ethics role-playing module, resume development, and reading assignments. Teaming skills are developed in section meetings through a presentation of material related to successful teaming and combination of in-class exercises and out-of-class projects. Teaming material presented includes information about team roles (leader, recorder, gatekeeper, timekeeper, member, etc.), development of a team charter, and keeping of a team logbook. In-class teaming exercises include exploration of differences between individual and team performance on word puzzles, analysis of the course syllabus, and the NASA moon-survival exercise. Out-of-class team projects include a campus traverse project requiring identification of project tasks, estimation and measurement of the time to complete those tasks, and completion of a research project in which students explore the use of multidisciplinary teams in recent aerospace developments such as the Joint Strike Fighter, SpaceshipOne, the Global Hawk UAV, and the Mars Rovers. The formation of teams varies from random selection, to thoughtful selection by the instructor, to self-selection by the students. No one method has proven to work best, so the approach is left to the discretion of the instructor.

Team-performed multidisciplinary design projects are built around a single story line: the development, air transport, and launch of a low earth orbit imaging/surveillance satellite. The air transport and rocket projects are based on design projects used previously in AE 101 and derived from [3] and [4]. The three design projects have multiple components, each relating to a different engineering discipline. The components were designed so that some could be omitted without loss of continuity; instructors choose among the components for course delivery. For all three projects, students are given background information packets that provide the required equations for functional and structural analysis of their design. Many of the equations have restrictions, so students are given reasonable ranges within which their values must fall. Project results are solely paper designs: model fabrication is not included in the course, as there is insufficient available space to support the 400-plus students. Design is performed by teams of three to five students. Deliverables include a written report and short presentation at the end of each project. Design project grading is on a team basis only; however, a peer evaluation of team members by each other performed at the completion of each design is a part of each student's individual grade.

The satellite project consists of three components: circular orbits analysis, imaging system design, and power system design. The circular orbits analysis involves graphical only analysis of the satellite orbits, reinforcing math and physics ideas, in particular vector concepts. The imaging system design requires students to determine parameters such as focal length, radius of curvature, optical resolution, and incoming light power for a spherical mirror and to choose an appropriate charge-coupled imaging device to meet size, resolution, and light power specifications (physics, CE). The electrical power system design involves choice of battery and solar-cell arrays to meet day and night power budgets (EE).

The aircraft design project (AE) involves design of an airplane to transport the satellite from its manufacture site to its launch site. Given minimum payload and range specifications, teams choose stall speed and cruise altitude, and then complete a preliminary design of a small or large transport including estimates of empty weight, fuel weight, wing area, wing geometry, aircraft center of gravity, tail moment, and tail geometry, and choice of engine and of flap type. Some course sections included a simplified engine design module as well (ME), where students used software (EngineSim, Glenn Research Center) to design an engine and chose parameters such as mach number (of incoming air), pressure ratios, number of stages for compressor and turbine, fuel to air ratio, and materials of the different components.

The launch system module consists of the design of a launch vehicle, including propellant choice, weight ratio calculation, propellant tank design, engine choice, and overall vehicle design (AE); design of a launch mount and the structural analysis of that design (CIV/ME); and design of a launch control sequencer including the hardware (using AND gates and OR gates) and software (activity diagram and pseudocode) (CE/SE). Optional components include design of an umbilical boom and structural analysis of that design (module requires integration as well) (CIV/ME), and design of a fueling system requiring piping system design, major loss, minor loss and pump power calculations, and pump selection (CIV/ME). The launch vehicle is a simple single-stage-to-orbit rocket designed to achieve the previously chosen circular orbit. The module includes the necessary systems integration to complete the design: The launch mount cannot be designed until rocket weight and thrust are chosen; fueling events within the launch sequencer depend on propellant tank dimensions within the rocket, as does the storage tank size and pump rates in the fuel delivery system; umbilical locations depend on the height of the propellant tanks.

The ethics module consists of reading assignments regarding the code of ethics of various professional societies, a role-playing exercise involving issues that arose in the construction of Denver International Airport, and a written analysis of the issues in the role-playing exercise. Resume development is timed to occur between the assembly on cooperative education and the ERAU Career Fair (see below): Students develop their own resume, receive critiques from their peers, make a revision, submit the resume to the instructor, and then make a final revision prior to the Career Expo. Reading assignments from the text [5] reinforce current section and assembly material. For example, reading on oral presentation precedes the first presentation; material on electrical circuits, the electrical system design of the satellite module; etc. The ethics, resume, and reading modules are graded on an individual basis.

Assemblies

During most weeks, EGR 101 students gather for a one-hour “all hands” assembly. Assembly activities include introduction of the course staff and college leadership; presentations by engineering student-group engineering professional societies; presentations by students who’ve been involved in cooperative education and internships; and presentations by engineering employers immediately prior to the annual fall ERAU Career Expo. It is anticipated that these four assemblies will be offered each year. Additional assemblies have included presentations by NASA astronauts (who happen to be ERAU alumni), the director of Eagleworks, Embry-Riddle’s Applied Aerospace Research Lab, and the vice-president for Research and Development at NASCAR. Topics in the additional assemblies vary from year to year.

Profession Awareness

The fall 2005 offering of EGR 101 included a profession awareness component. Students were required to attend one professional society meeting (student activity or professional meeting), one college-delivered activity outside their chosen degree area, and one other college delivered activity. Activities included a wind-tunnel exercise (AE), a physical tour of a GE turbofan engine (AE), a site visit to a local manufacturer of simulation systems (CE), helping build a concrete canoe (CIV), simple truss construction and destructive testing (CIV), construction of a Morse code transmitter (EE), gear-ratio investigation with a remote control race car (ME), and a real-time computation lab (SE). Profession awareness activities are intended not only to expose students to areas outside their degree, but also to help first-time students build networks with the upper-division students conducting the profession-awareness sessions.

ASSESSMENT

EGR 101 assessment includes a formal assessment instrument (survey of EGR 101 students), student evaluation of section instructors, faculty assessment of section performance, informal discussion by section instructors during weekly staff meetings, and informal comments volunteered by students over the course of the semester. Results presented here are based on delivery of the assessment instrument at the end of each of the fall 2004 and fall 2005 semesters.

At the end of each fall semester, EGR 101 students take an online survey to complete the formal assessment instrument. Participation is voluntary and has been about 25% of the EGR 101 enrollment; i.e., about 100 students each semester. The survey instrument questions that were common between the two years are shown below in Table II. Students are asked to respond "strongly agree," "agree", "neutral," "disagree," or "strongly disagree" to each of the statements in the instrument. The results of the assessment are show in Table III; for simplicity, the percentage of responses that were "strongly agree" and "agree" were added together and graphed in Figure 1 to illustrate overall delivery improvement from academic year 2004 to 2005. The questions were selected for assessment of how well the delivery met course objectives, ABET requirements, and student expectations.

Assessment results indicate that EGR 101 is achieving COE objectives of increasing student awareness of degree programs outside their chosen major (Q1 and Q3) without having them feel shortchanged regarding material in their own degree (Q2): Agree or strongly agree responses to those questions are near or exceed 60%. EGR 101 is also achieving course learning objectives related to teaming (Q4), design (Q6), ethics (Q8), student activities (Q11), and co-ops and internships (Q12). Results regarding resume development (Q10) and preparation for the Career Expo (Q9) are not as positive and indicate areas for improvement to the faculty delivering the course. The initial year-to-year increase in "agree" or "strongly agree" responses hopefully reflects improvement in the ability to deliver the course with experience.

Preliminary measures of in-program retention and transfers (unavailable for publication) indicate that EGR 101 is not achieving its COE goal of facilitating transfers into the smaller programs; in fact, while retention within the COE is steady, the smaller programs may be losing students to the larger AE program. It is hypothesized that the relatively small number of students from each program spread out over all the sections of EGR 101 is preventing students in those smaller programs from making as many connections with other students in the same programs. In response to this, smaller programs will have special sections of EGR 101 devoted to them in the future. Enrollment in those sections will still include students from other programs, particularly AE, but the situation will change from having 27 AE students, 1 CIV, 1 CE, 1 ME to having sections with 15 CIV and 15 AE, 15 CE and 15 AE, etc. Furthermore, the instructor for those sections will come from the same non-AE program as the students being concentrated into one section. Content will remain the same, but it is expected that faculty will choose components that are appropriate to the particular degree program to emphasize.

Table II. Questions on the EGR 101 assessment instrument.

1.	EGR 101 was helpful in making me more aware of other engineering programs in the College of Engineering.
2.	EGR 101 introduced enough topics related to my chosen discipline of engineering.
3.	EGR 101 provided an opportunity to interact with students of other disciplines that I normally would not have had.
4.	EGR 101 helped me to improve my ability to work in a team environment.
5.	EGR 101 gave me an opportunity to meet my peers and make a strong connection with them.
6.	EGR 101 made me more aware of the engineering design process.
7.	EGR 101 gave me an opportunity to become better acquainted with the University's campus and what it has to offer.
8.	EGR 101 introduced an engineering code of ethics to me and made me aware of its importance.
9.	EGR 101 was helpful in preparing me for the Career Expo.
10.	EGR 101 provided help for writing a resume.
11.	The assembly at the beginning of the semester on student clubs and activities was informative and useful.
12.	The assembly on co-ops and internships was informative and useful.
13.	Overall, EGR 101 was a good and useful experience.

Table III. Results (percentages of responses) of the EGR 101 assessment for fall 2004 and fall 2005. AY: academic year; SA: strongly agree; A: agree; N: neutral; D: disagree; SD: strongly disagree.

Question Summary	AY	SA	A	N	D	SD
1. Intro to Other Programs	04	17.1	41.2	21.3	14.7	5.7
	05	26.3	48.7	14.5	7.9	2.0
2. Enough on Chosen Discipline	04	34.1	43.6	13.3	5.7	3.3
	05	31.6	51.3	9.2	2.6	4.6
3. Chance to Meet Peers of Other Eng. Disciplines	04	19.0	42.7	21.8	14.2	5.7
	05	16.4	48.7	30.9	5.9	1.3
4. Teaming Skills Improvement	04	28.4	48.3	15.2	6.2	1.9
	05	30.3	49.3	12.5	5.9	2.0
5. Made Strong Connection with Peers	04	29.4	47.9	17.1	4.3	1.4
	05	30.3	49.3	14.5	3.3	2.0
6. Intro to Design Process	04	37.9	50.2	6.6	3.8	1.4
	05	36.2	48.7	11.2	3.3	0.0
7. Familiar with Campus	04	11.8	43.6	33.2	7.6	3.8
	05	17.1	41.4	28.3	10.5	2.6
8. Intro to Eng. Ethics	04	28.9	51.7	10.0	6.6	2.8
	05	32.9	49.3	14.5	2.0	1.3
9. Info on Career Expo	04	8.5	31.3	36.5	15.2	8.5
	05	7.9	44.7	35.5	9.9	2.0
10. Info on Resume Building	04	4.7	19.9	24.2	28.0	25.6
	05	13.8	23.7	36.8	20.4	8.6
11. Assembly on Clubs Useful	04	10.0	32.3	35.1	16.1	6.2
	05	17.1	48.7	25.0	6.6	2.6
12. Assembly on Co-ops Useful	04	27.0	49.3	18.0	4.3	1.4
	05	26.3	47.4	19.1	5.3	2.0
13. Overall Good Experience	04	23.7	47.4	17.5	8.5	4.3
	05	32.9	52.6	11.2	3.9	2.0

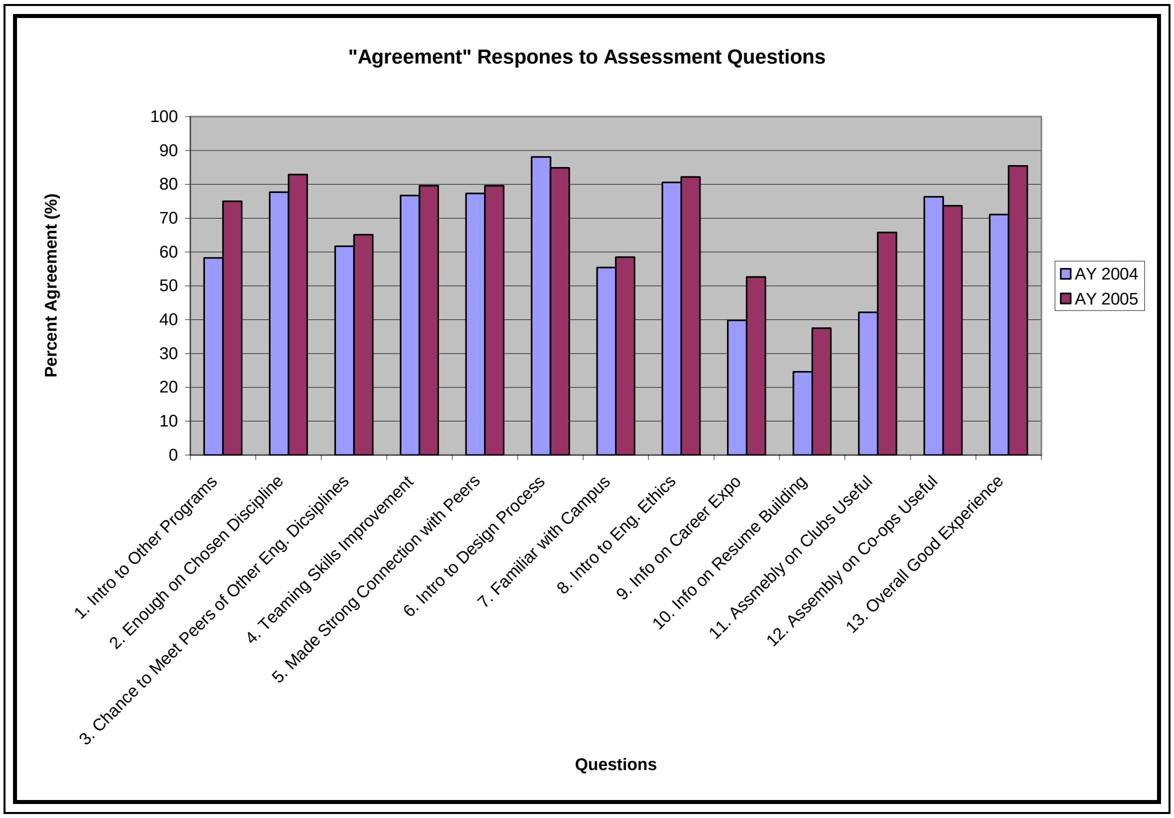

Figure 1. Overall improvement in delivery and meeting of course objectives for EGR 101 from fall 2004 to fall 2005.

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