# THE INTERDISCIPLINARY UNDERGRADUATE CURRICULUM AT THE UNIVERSITY OF DENVER

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***Abstract*** *- As part of an innovative approach to interdisciplinary engineering education, undergraduate students in the Department of Engineering at the University of Denver complete a four-year sequence of specialized courses. In the first two years of the program, students develop team working and communication skills, are exposed to engineering concepts, and apply knowledge and skills in the areas of Mechanical, Electrical, and Computer Engineering. In addition to developing fundamental skills in Engineering and the Sciences, students complete courses in technical writing and public speaking that are closely integrated into the first year engineering sequence. After two years of experience with the three disciplines offered by the department, each student declares a disciplinary focus. The delay in the selection of a program is designed to allow students to have a better understanding of each discipline in order to achieve a broad educational base, and to improve persistence in the freshman and sophomore years. During the remaining two years, interdisciplinary skills are further developed through two design experiences in the junior and senior years. Assessment strategies for the integrated sequence of courses are covered to show how success is measured.*

*Index Terms – Freshman Engineering Experience, Integrated Communication and Technical Training, Interdisciplinary Design Project*

## INTRODUCTION

The advent of ABET's Criteria 2000 motivated the faculty of the Department of Engineering to create a truly innovative approach to engineering education [1,2,3]. The guiding principle was to create an interdisciplinary approach to disciplinary degrees. The interdisciplinary sequence is defined as a sequence of courses where all students take the same courses in the first two years; they declare their discipline at the end of the sophomore year. This approach develops well-rounded engineers with experience in the fundamentals of engineering principles from Electrical, Computer, and Mechanical Engineering. An integrated sequence is also woven throughout the four-year program to emphasize the interdisciplinary nature of the modern engineering world. In the freshman and sophomore years they work in teams to develop interdisciplinary engineering projects. After the students elect a specific discipline in the junior year, they participate in a multidisciplinary design project in the junior year. Multidisciplinary is used in the sense that each student has a specialized set of skills and knowledge learned in the disciplinary courses associated with Computer, Electrical, or Mechanical Engineering. The junior year course sequence combines knowledge from the specific discipline to produce a truly multidisciplinary team where each member contributes skills from a specific discipline to the solution of the problem. Upon completion of the junior level design process, the students enroll in a full year senior design project. The end result of the program is to produce engineers who have a thorough understanding of the other disciplines through the interdisciplinary course sequence and have had an opportunity to work on team-oriented, multidisciplinary problems.

The following sections provide more detail as it relates to the delivery of the curriculum and the unique nature of the Engineering program offered by the University of Denver. Assessment of this curriculum is also briefly discussed to show how the objectives of the program are monitored and evaluated. Figure 1 shows how the integrated sequence is entwined in the engineering program.

## BACKGROUND AND CURRICULUM OVERVIEW

The Department of Engineering was created in 1984, nine-years after the closing of the School of Engineering. It was conceived as a small, single-program department designed to provide a broad, basic engineering education. From the beginning it was clear that a single BSE program would not be viable in the long term but enrollments and faculty size worked against creating separate departments. Nevertheless, the University approved the creation of two new disciplinary degrees within the Department in 1987 (BSEE and BSME). After ten years of experience as a single department offering distinct disciplinary degrees it was apparent that there were significant advantages to the students as a result. With the introduction of ABET's Criteria 2000, the department's faculty decided to create a totally new approach to engineering education by building on those experiences.

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The new curricula, first accredited in 1998, emphasize several tenants: a common curriculum for the first two years; an integrated sequence of lab-oriented, inter- and multidisciplinary, team-effort courses throughout; emphasis on leadership skills; emphasis on communications skills; and a thorough assessment program.

| | COMMON CURRICULUM | | DISCIPLINARY CURRICULUM | |
|---|---|---|---|---|
| | First Year | Second Year | Third Year | Fourth Year |
| University Core | **English Writing I,II**<br>**Campus Connection**<br>**Creative Expression** | Foundations<br>English Literature | Foundations | Foundations/<br>Thematic Core<br>Study Abroad |
| **Integrated Sequence** | **Concepts I,II,III** | **Applications I,II,III** | **Integration I,II** | **Senior Design I,II,III** |
| Fundamentals | Chemisty w/Lab<br>Physics I,II, w/Lab<br>Calculus I,II,III | Physics III<br>Differential Eqs<br>Multivariate Calc.<br>Engr Thermo I<br>Mechanics I,II<br>Circuits I,II<br>Digital Design<br>Programming I, II<br>Assessment I | Economics & Ethics<br>Linear Algebra<br>Optional | Assessment II |
| Disciplinary Programs | | | Required Courses | Required Courses<br>Technical Electives<br>Open Option |

FIGURE I
OVERVIEW OF THE FOUR-YEAR UNDERGRADUATE PROGRAM AT DU

The choice of a two-year common curriculum was made with several objectives in mind. The first was to provide students with the time to make a smart, educated decision on their major. As designed, the program uncovers the role that the three disciplines (EE, ME and CpE) play in the development of engineering products. The disciplines are not placed in competition, but rather are shown in complementary roles. The second objective was to deliver a program that permits students to receive a broad foundation in all three disciplines that pays dividends in their understanding of inter- and multidisciplinary projects and in passing the required FE exam. The third objective was to provide students with experience in the needed skills for advanced efforts in the upper-class years – namely, communication, team, and laboratory expertise. And finally, it was hoped that this effort would improve student persistence.

To meet these objectives, a curriculum-wide approach was developed. A new BS in Computer Engineering was added to the departmental offerings. There was a need to add this discipline to help in the realization of the projects that would be necessary to achieve other program goals. A novel, integrated sequence of courses was created that would permit students to practice analysis, design and evaluation of team-oriented, inter- and multidisciplinary projects. This sequence culminated in a year-long capstone design project. Furthermore, it was determined the integrated sequence would be best delivered by faculty members from at least two separate disciplines. Hence most courses in the integrated sequence are co-taught.

A fundamental skill that often is underemphasized in engineering programs is the ability to communicate. Our curriculum is designed to emphasize oral, written and drawing skills beginning in the first year and continuing throughout all four years. To help students prepare for the global environment they will be entering upon graduation, the program is designed to provide engineering students with a study abroad experience at the undergraduate level without losing time towards the sought degree. This program initiated in 1999 and continues today.

The total package of the engineering curricula at the University of Denver is designed to provide students with real-world experience to prosper in the current global economy and to play a key role in future innovations. A complex and thorough assessment program was developed to support the curricula to assure we were achieving our objectives.

## ASSESSMENT STRATEGY

In consonance with the ABET Criteria 2000, an assessment strategy was created that covered 10 major outcomes:

A. Develop a strong grounding in the fundamentals and how to apply them.

B. Develop an ability to analyze engineering problems and synthesize solutions including the design and conduct of experiments.

C. Develop excellent communications skills.

D. Be able to accomplish engineering tasks independently.

E. Be able to enter industry with the needed skills to be able to solve real-world problems.

F. Know and uphold ethical and professional standards of the profession.

G. Develop and practice the ability to function effectively on interdisciplinary and multidisciplinary teams.

H. Develop the ability to resolve open-ended design problems.

I. Be capable of functioning in a global environment

J. Be prepared for a life of continual learning consisting of formal and/or informal course work and self-education.

These program outcomes are measured throughout the sequence of integrated courses (as well as in other more traditional courses) based on the matrix shown in Table 1. Due to the nature of courses that emphasize team working skills, interdisciplinary design, and written and oral communication, outcomes B,C,E,G, and H are evaluated totally within the integrated sequence. It is worth noting that the communications skills are developed in close cooperation with the departments of English and Human Communications.

The application of these criteria to the integrated sequence of courses is outlined in the following sections with specific examples as they relate to the development of technical, communication, and team-working skills.

## ENGINEERING CONCEPTS

In order to achieve the objectives outlined in the previous section, students develop skills in the freshman year Engineering Concepts courses in mechanical, electrical, and computer engineering design [4]. A three-quarter sequence is utilized to introduce students to fundamental knowledge in the three disciplines and implement designs that are interdisciplinary in nature. The three courses flow smoothly such that once students develop design related skills in the first quarter, they build on mechanical skills in the development of electromechanical systems in the second quarter, and develop electrical systems for computer engineering projects in the third quarter.

TABLE 1
OVERVIEW OF THE INTEGRATED SEQUENCE ASSESSMENT STRATEGY

| COURSE | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| Concepts I | | | | | X | | | | | |
| Concepts II | | X | X | | | | | | | |
| Concepts III | | | X | | | | X | X | | |
| Applications I | | | | | X | | | | | |
| Applications II | | | | | | | | | | |
| Applications III | | X | X | | | | X | | | |
| Integration I | | | | | X | | | | | |
| Integration II | | | X | | X | | X | | | |
| Design I | | X | | | X | | | | | |
| Design II | | | X | | X | | | | | |
| Design III | | X | | | | | | X | | |

As shown in Table 1, the first year Engineering Concepts sequence evaluates the student's ability to develop skills to solve real-world problems, to analyze and synthesize solutions, to design and conduct experiments, to utilize oral and written communications skills, to work in interdisciplinary and multidisciplinary teams, and to resolve open-ended design problems. These skills are assessed based on project development in each quarter of the sequence. Presentations in both written and oral form and student evaluation of teamwork are utilized for this process.

In the first quarter of Concepts, students are introduced to simple mechanical systems and team working skills. They are required to construct a trebuchet and measure the performance of the finished project. Students work in teams to design, construct, and test the project. In the second quarter of Concepts, students develop an electromechanical anemometer to measure wind speed. The performance of the system is measured and tested. In the third quarter of Concepts, the students control an autonomous robotic system. The students are provided an objective and are required to integrate the electrical, mechanical, and computing aspects to reach a target.

When the students complete the freshman year, they are exposed to design principles and techniques from all three disciplines and have developed skills that will carry into the sophomore sequence of technical and integrated courses. The Concepts courses are also tied with courses in technical writing and technical speaking so that students are prepared to develop projects and present the results of their work.

## ENGINEERING APPLICATIONS

The sophomore Engineering Applications sequence of courses combines material from the common curriculum that includes circuits, programming, mechanics, and digital design. Students work in teams during the three-quarter sequence to develop and implement laboratory experiments. The first two quarters focus on the development of DC and AC circuits, control of electromechanical systems, and sequential programming design using commercially available packages. The third quarter of the Engineering Applications sequence is the capstone in this sequence and serves as a bridge to the junior design sequence [5,6]. The second-year capstone experience requires student use of skills developed in all previous engineering courses. Engineering Applications III is a novel interdisciplinary course that integrates knowledge gained and skills acquired from the freshman introductory, circuits, mechanics, and programming courses. The course is built around the concepts associated with automated data acquisition systems.

The Engineering Applications sequence measures the student's abilities to design and conduct experiments, develop excellent communication skills, and develop and practice the ability to function effectively on interdisciplinary teams. The assessment of these outcomes is based on laboratory reports and measurements related to experiments performed throughout the course sequence. The students should exhibit a more mature approach to the outcomes based on their experience in the freshman sequence.

At the conclusion of the sophomore year, students select a discipline for their upper division study. This decision is based on their experience and preference of study in the freshman and sophomore year. Our desire is to have a fairly even distribution of students among the three disciplines so that multidisciplinary design project teams can be realized in the junior year.

## INTEGRATION

The two-quarter Engineering Integration course is a junior-level introduction to design engineering. In this course sequence, the students are given a tightly constrained project. The students are formed into engineering teams of 3 or 4 in the first class period. Ideally, each student engineering team should have at least one EE, ME and CpE. The teams report to the instructors (who are referred to as the management). Each student is provided with a summary of the project in the form of an RFP (request for proposal). In the RFP is the description of the constraints, some physical attributes of the robot to be designed, and the missions the robot is to perform.

The RFP also contains checkpoints or milestones laid out over the 20 week duration of the sequence. The first two milestones consist of a subsystems test, and a simple navigation test and they are carried out in the first 10 weeks. Additionally, the student teams brainstorm to come up with design alternatives that will meet the criteria set forth in the RFP. The teams develop a vehicle platform that they design as illustrated in figure 2, and the teams are required to make a choice between using a set of parts provided by "management" or acquiring all the parts on their own. In either case, the teams must meet a cost constraint. The remainder of the course is focused on the construction of the platform and completion of two additional milestones. The robot must pass an advanced navigation test and perform advanced navigation with search or delivery.

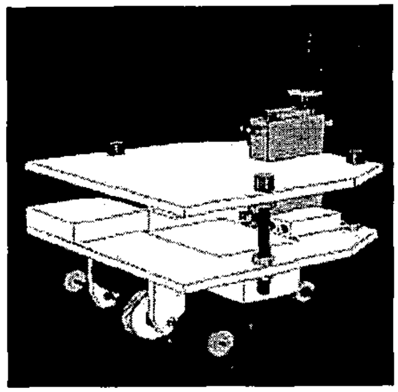

FIGURE 2
CONCEPTUAL DRAWING OF AUTONOMOUS ROBOT

As noted earlier, all students who take this course have a common background, but in addition they have acquired two quarters of disciplinary study. The lectures in the Integration course are designed to provide insight into how to integrate their technical skills into the project. During the lab periods in the first term, the students are instructed to use numerical controlled lathes and milling machines, rapid prototyping machine, and circuit card milling machine (T-Tech®). The students are also required to interface their microcontroller to various devices (i.e. motors, sensors, servos). The lab periods in the second term are devoted to students building and testing their robots.

At the conclusion of the junior year, each student has participated in a multidisciplinary design project. The students are assessed on their communication, technical, and team working skills. This managed design project in the junior year prepares students to enter the open-ended design process in the senior year with additional skills and experience.

## SENIOR DESIGN

In the senior year, as part of the preparation to enter industry as engineers-in-training (EIT), students develop and implement a design project across three academic quarters. The department of engineering solicits proposals for design projects from internal and external customers to provide student teams with choices for the design experience. Once the proposals are reviewed internally, the students form groups and compete for projects that are suited to their skills and interests. Faculty advisors are assigned to counsel and guide the students through the design process. In addition to receiving departmental support, students are encouraged to seek advice and support from industry as it relates to their specific project. The projects may or may not be multidisciplinary in nature.

The Engineering Design Project in the fourth year serves as a bridge between the academic design experience and an industry design experience. The skills developed in the previous three years are utilized as students seek out projects, develop and evaluate open-ended solutions, communicate with their peers and supervisors, and deliver a finished product. While students are not necessarily working in multidisciplinary teams, their ability to function as a group is critical to the success of the project. The multidisciplinary nature of the project is seen in the ability of the engineering students to convey their designs to the broad audience of engineers who listen to their reports who may not have experience in their technical field. Communication skills are critical as well as the technical skills necessary to satisfy the customer and the supervisor of the project.

## CONCLUSIONS

At the completion of the four-year Engineering program at the University of Denver, students have a unique set of skills that combine a rigorous engineering education with team-work, communication, and interdisciplinary experience. Additional documentation of success is measured in the form of student persistence rates. One-year persistence rates are displayed in Table 2. While the precise reasons for the improved rates are not known, the strong consensus among the faculty is that it is in large part due to the interdisciplinary curriculum and integrated approach. We will continue to track these data.

The integrated sequence of courses plays a key role in the development of vital technical, communication and leadership skills. The combination of these skills provides a broad educational experience that will hopefully lead to a philosophy of life long learning. Students are required to interact to design, develop, and present engineering projects from the freshman year to the senior year. Additionally, students are provided a two-year introduction to basic skills and techniques vital to all engineering disciplines prior to their selection of a specific program of study. This delayed declaration allows students to find a good match with their interests and abilities to develop a solid grounding in a specific program of study.

A thorough assessment of this program is vital to the long-term success of this innovative approach to engineering education. Modifications to the delivery of the program and monitoring of the outcomes are performed as needed to ensure the proper match of material to the programmatic outcomes. Data will be collected and disseminated as the program grows and develops to meet the evolving needs of the Engineering workforce for the 21st Century.

Table 2
Student Persistence Rates

| Entry Year | One-year persistence rate |
|---|---|
| 1997 | 54% |
| 1998 | 55% |
| 1999 | 52% |
| 2000 | 80% |
| 2001 | 85% |

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