A Nontraditional Approach: Creating, Implementing and Overseeing A Multidisciplinary Electromechanical Engineering Program

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Abstract

This paper describes the design, development, and oversight of a five year dual-discipline program in Electromechanical Engineering (ELME) at Wentworth Institute of Technology. It begins with the basic rationale behind the decision to design an interdisciplinary engineering program at the undergraduate level, and continues with a history of the program as it developed and matured over the past ten years, culminating with accreditation under EAC Criteria 2000. An in depth comparison is also made between the Electromechanical Engineering program and typical four year single-discipline programs, in both electrical and mechanical engineering.

Integral to the process of this program's design and development was the establishment of a committee structure—the oversight component—consisting of an interdisciplinary group of faculty with a vested interest in the program's success, its students' achievements, and its ongoing work. The program committee currently consists of eleven faculty members who have volunteered from the Electrical, Mechanical, Applied Science and Mathematics, Humanities, Social Science and Management Departments. The committee is at the center of all program-related decisions from student entrance requirements, course development, assessment, curricular modification, and ultimately program accreditation. The working relationships that the committee members have cultivated along with the many and varied problems that they have encountered and solved in the past decade are examined in this paper.

Critical to the overall success of the program was both the initial and long-term willingness of the Wentworth administration to support the unusual concept of a five year dual-discipline engineering program overseen by a faculty program committee. A traditional departmental structure was not part of the program design. The success of the Electromechanical Engineering program is also the result of collaboration with all of the relevant constituent groups. The committee realized that designing a multidisciplinary curriculum was only part of the problem. An equally important component of a successful multidisciplinary curriculum is the oversight component that involves combining and coordinating course offerings from two traditionally separate engineering departments. This proved to be the real challenge.

Introduction

This paper begins with a brief history of the Electromechanical Engineering program now in its tenth year at Wentworth. It includes the original motivations behind the development of a five year dual-discipline curriculum at the undergraduate level, and an in-depth comparison between this dual-discipline and a typical four year single-discipline program in both electrical and mechanical engineering offered at other institutions.

Ultimately, the decision to offer this unique amalgam of traditionally individual engineering disciplines evolved into the program's mission statement, which states, in part, the intent to "... develop students who are able to analyze, synthesize, and design electrical, mechanical, and electromechanical systems, [and to] ... prepare students for a productive professional career in [the new field of] ... electromechanical engineering."

We found that for a dual-discipline engineering program to develop and successfully fulfill its mission objectives required a break from the traditional organizational structure of an academic department. Instead, we brought together an interdisciplinary group of interested faculty who were able to work within the bounds of a new program management framework — a faculty oversight committee — charged with overall program supervision. How and why this type of program committee evolved, the role that the Wentworth administration played in its inception and development, how the committee solves the day-to-day challenges it faces, how it currently sees its oversight role, and why it has ultimately been successful over the past decade, are all investigated throughout this paper.

Rationale For An Electromechanical Engineering Program

In the late 1980s and early 1990s, professionals were saying at ASEE conferences and writing in journals that colleges and universities must begin preparing multi-disciplined engineering graduates, which will be needed by industry in the near future. Wentworth's faculty, administration, and Industry Professional Advisory Committee members decided to take a leadership role in engineering education and began developing a dual-discipline program in electrical and mechanical engineering. We believed that a new program, Electromechanical Engineering, with an ability to develop graduates educated in both engineering areas would be highly sought after by business, industry, government, and academia. Once we finally decided that a new generation of professional engineers should be educated in this area, our attention turned to how to develop and implement such a curriculum. Wentworth's administration did not want to merge the electrical and mechanical faculty together to create one new program because the traditional separate programs were also slated to remain as viable entities. The solution was to ask for volunteers from full-time faculty to design, develop, and oversee this new engineering curriculum without merging the traditional departments. This design and development has resulted in a dual-discipline program that differs in significant respects from single discipline engineering programs, as the following section illustrates.

Program Comparisons

In the past ten years, the Electromechanical Engineering Committee at Wentworth has overseen the graduation of six classes, has applied for and received ABET EAC accreditation, and has

consistently attracted a stable first year class of approximately 60 students. During this time, the program has also matured through two modifications and has evolved into its current curriculum. Its primary mission, however, has remained unchanged. The most recent iteration of this five year 176-credit cooperative education program is grouped by subject area in this section.

The table below compares Wentworth's Electromechanical Engineering (ELME) program to both a classical single-discipline four year 130-credit electrical engineering (EE) program and a mechanical engineering (ME) program. For the purpose of this comparison, the programs are organized into major areas of study with all courses grouped under one of ten distinct subject headings. The subject areas are: *mathematics, science, electrical engineering, mechanical engineering, engineering design, engineering systems and engineering electives, humanities and social science, general electives, and other required courses*. Table 1 shows the comparison of the three engineering programs for each category. It also includes the number of credits and percentage of the total credits for each category. The following sections of this paper list the individual courses and credits in each category for each program.

Table 1
Comparison by credits and percent of total required credits

Program by major subject area	A dual-discipline 5-year Electromechanical Engineering (ELME) program	A typical 4-year single-discipline Electrical Engineering (EE) program	A typical 4-year single-discipline Mechanical Engineering (ME) program
Mathematics	28 credits (16%)	22 credits (17%)	20 credits (15%)
Science	12 credits (7%)	16 credits (12%)	16 credits (12%)
Electrical Engineering	30 credits (17%)	24 credits (19%)	4 credits (3%)
Mechanical Engineering	32 credits (18%)	4 credits (3%)	32 credits (25%)
Engineering Design	18 credits (10%)	8 credits (6%)	8 credits (6%)
Engineering Systems	8 credits (5%)	4 credits (3%)	---
Engineering Electives	3 credits (2%)	8 credits (6%)	16 credits (12%)
General Electives	6 credits (3%)	12 credits (9%)	2 credits (2%)
English, Hum. Soc. Sc.	28 credits (16%)	24 credits (19%)	24 credits (19%)
Other Required Courses	11 credits (6%)	8 credits (6%)	8 credits (6%)
	176 credits	130 credits	130 credits

Mathematics and Science — The comparison of these categories shows that the ELME program has six to eight more credits than either a traditional EE or ME program. Some of these extra credits result from the conscious decision to begin our program with an Engineering Mathematics course instead of Calculus I, to establish a baseline for all students. Some students may receive credit for this course based on the results from our Advanced Mathematics Placement exam. This first mathematics course is not typical in a traditional four-year

engineering program. The mathematics content for all the programs studied ranges from twenty to twenty-eight credits as shown in Table 1. The three science courses (12 credits) in the ELME program are fewer than the four science courses (16 credits) for both other disciplines that were used in this study. Both traditional engineering programs include an additional physics course that is not contained in the ELME program. However, many of the topics are covered in the ELME program's additional engineering courses.

ELME	EE	ME
Engineering Mathematics (4)	Calculus I (4)	Calculus I (4)
Calculus I (4)	Calculus II (4)	Calculus II (4)
Calculus II (4)	Multivariable Calculus (4)	Multivariable Calculus (4)
Calculus III (4)	Differential Equations (4)	Differential Equations (4)
Differential Equations (4)	Linear Algebra (4)	Engineering Mathematics (4)
Linear Algebra & Matrix Theory (4)	Probability and Statistics (4)	
Probability & Statistics (4)		
Chemistry (4)	Chemistry (4)	Chemistry (4)
Engineering Physics I (4)	Physics I (4)	Physics I (4)
Engineering Physics II (4)	Physics II (4)	Physics II (4)
	Wave and Motion (4)	Wave and Motion (4)

Electrical Engineering — A comparison of this core set of courses shows that the ELME program and a typical EE program offer a total of eight electrical engineering courses. Both programs offer substantially the same number of credits, the ELME program has thirty credits compared to thirty-two credits for a traditional EE program. The four year EE program had two core elective electrical engineering courses that were included in this category.

ELME	EE	ME
Network Theory I (4)	Network Theory (4)	Electric Circuit Theory (4)
Network Theory II (3)	Signals and Systems (4)	
Analog Circuit Design (4)	Intro. to Electronics (4)	
Digital Systems (4)	Intro. to Logic (4)	
Embedded Comp. Systems (3)	Electromagnetics (4)	
Motors and Controls (4)	Electrodynamics (4)	
Signal and Systems (4)	EE Elective (4)	
Feedback and Controls (4)	Track Elective (4)	

Mechanical Engineering — A comparison of the core mechanical engineering courses yields similar results as the EE comparison. Both the ELME program and the ME program offer a total of eight courses in this major subject area. Both programs offer the same number of credits thirty-two credits.

ELME	EE	ME
Engineering Statics (4)	Eng. Mechanics (4)	Eng. Mechanics (4)
Mechanics of Materials (4)		Mech. of Materials (4)
Eng. Thermodynamics (4)		Thermodynamics (4)
Materials Science (4)		Fluid Mechanics (4)
Engineering Fluids (4)		Heat Transfer (4)
Engineering Dynamics (4)		Materials Science (4)
Engineering Heat Transfer (4)		Machine Design I (4)
Adv. Mechanics of Materials (4)		Machine Design II (4)

Engineering Design — A major component of any engineering program is engineering design. The ELME program has a sequence of five design courses for a total of eighteen credits that thread throughout the program and constitute approximately 10% of the coursework. By comparison, the courses designated design, or contained design in the catalog description, in the EE or ME programs make up no more than eight credits or 6% of these majors. This difference is significant and reflects the importance that Wentworth places on engineering design.

ELME	EE	ME
Intro to Engineering Design (4)	Intro to Engineering (4)	Intro. to Engineering (4)
Electromechanical Design (3)	Senior Design (4)	Eng. Des. using CAD (2)
Engineering Thermal Design (3)		Fund. of Eng. Design (2)
Senior Design I (4)		
Senior Design II (4)		

Engineering Systems and Engineering Electives Courses — The ELME program has two system courses and one engineering elective course for a total of eleven credits. The EE program listed one systems course and three technical electives for a total of twelve credits. The ME program required no systems courses but five technical electives for eighteen credits. The ELME system courses are team taught and they show the similarities between electrical, mechanical, thermal, and fluid systems.

ELME	EE	ME
Electromechanical Systems I (4)	Systems Engineering (4)	
Electromechanical Systems II (4)		

Engineering Elective (3)	Technical Elective (4)	Core Elective (2)
	Technical Elective (4)	Technical Elective (4)
	Technical Elective (4)	Mechanical Elective (4)
		Concentration Elec. (4)
		Concentration Elec. (4)

General Electives — The ELME has two general elective courses for a total of six credits. These courses are used by students to broaden their interest either in a technical or non-technical area

and must be approved by a student's advisor. Electives listed for either the EE or ME majors appeared to be more technical and were included in the engineering category or in the engineering elective category.

ELME	EE	ME
General Elective (3)		
General Elective (3)		

English, Humanities and Social Science — All three programs offer either twenty-four or twenty-eight credits in English, technical communications, humanities, and social science.

ELME	EE	ME
English I (4)	English Composition (4)	English Composition (4)
English II (3)	Sociohumanistic (4)	Sociohumanistic (4)
2 nd Year Social Science (3)	Sociohumanistic (4)	Sociohumanistic (4)
2 nd Year Social Science (3)	Sociohumanistic (4)	Sociohumanistic (4)
Technical Communications (3)	Sociohumanistic (4)	Sociohumanistic (4)
3 rd Year Hum./Soc. Sc. (4)	Sociohumanistic (4)	Sociohumanistic (4)
4 th Year Hum./Soc. Sc. (4)		
5 th Year Hum./Soc. Sc. (4)		

Other Required Courses — A review of this subject area identifies those courses which usually are specified by an institution for graduation therefore not grouped in one of the other categories. The ELME program has three courses for eleven credits. Both traditional programs also have three courses but list only eight credits. The Freshman Advising Seminar course did not specify any credits although it was a required course.

ELME	EE	ME
Introduction to Engineering (4)	Freshman Advising Seminar	Freshman Advising Sem.
Computer Science (4)	Eng. Computation (4)	Eng. Computation (4)
Engineering Economy (3)	Computer Elective (4)	Instru.& Th. Exp. (4)

Summary of Cross-Discipline Engineering Courses — Present day electrical engineering programs offer only one mechanical engineering course and, similarly, mechanical engineering programs offer only one electrical engineering course. This single cross-discipline course is in stark contrast to the ELME program, which offers an equal number of courses (eight) from both classical engineering areas and substantially similar program credits. Thus, the addition of one more academic year to a classic four year engineering program results in a tremendous amount of additional engineering coursework being included in a dual-discipline engineering program without any substantive loss in program coverage or depth.

Committee Structure

The interdisciplinary organizational structure of the Electromechanical Engineering program presently consists of eleven full-time faculty members representing all the major academic areas of the program. Three faculty members are from the electrical area, four are from mechanical and manufacturing, one faculty member's education is in both electrical and mechanical, another's is in physics, one faculty member is from the Applied Mathematics and Science Department and one is from the Humanities, Social Science and Management Department. This interdisciplinary committee structure is unique on our campus, as it is on most others, and provides greater faculty responsibility for the program and more student/faculty interaction, as well as better communication with all constituent members than the normal departmental structure.

We believe that the principle reasons why the committee structure works on the Wentworth campus are: (1) the relatively small size of the full-time student body (approximately 2800 full-time day students); (2) the relatively flat organizational structure (department heads report directly to the Provost); and (3) the cooperation of faculty from different departments who are encouraged to work together on program self assessments.

The committee meets biweekly, or more often as needed, to discuss all aspects of the program. Since its inception, this committee has addressed many academic and managerial issues associated with operating an interdisciplinary program. Issues such as student advising, curriculum development, course changes, admission, re-admission, transfer credit guidelines, scheduling, preparatory courses for the Fundamentals of Engineering (FE) exam, and faculty scheduling related to team teaching have been discussed and acted upon. The interdisciplinary nature of the committee has been very successful and it has moved the program significantly forward in the past ten years. The committee uses a team-teaching approach for as many interdisciplinary courses as possible. The committee meetings provide a built-in and an ongoing review, assessment, and feedback process for the program. The committee continuously works on every aspect of the program and frequently considers how to implement improvements. Major curriculum changes become agenda items for the next Industrial Professional Advisory Committee meeting. Thus, the committee provides an easily acceptable avenue for creative growth and the future of the program. The faculty members act with the realization that their voice is heard and the program succeeds, not because there are top-down directives from the administration, but rather because of the collective interaction and cooperation of all the members of the team.

Committee Structure versus Department Structure

Over the past decade our experiences have convinced us that a faculty committee structure has produced a culture and a way of doing things that has inherent advantages over that of a departmental structure. Our experience has left us with the conclusion that a program committee structure is a bottom-up approach and lends itself to the creation of leadership in the faculty who are involved in the program. This structure is usually in sharp contrast to the more traditional departmental configuration, which fosters a classical management structure that is more of a top-down approach in which faculty are expected to perform duties as articulated by the department

head. We have also found that students readily accept an interdisciplinary design-team structure because they see that the faculty overseeing their program is organized in the same way. Leading by example has not gone unnoticed by the students. In addition, junior faculty members see that their obligation to do what is best for the program, and the students, is encouraged by their colleagues and they are more willing to articulate their views on a particular issue. This type of collegial activity lends itself to more rapid growth of a junior faculty member's contribution to course and program development.

We find that the traditional departmental structure encourages faculty to consider the courses he or she is teaching as paramount and the program in which they are contained is a secondary consideration. In contrast to a department structure, a program committee structure encourages the faculty to consider what is best for the program first and their individual courses second.

Because committee meetings often revolve around student issues – grades, transfer credits, student achievement levels, attendance, etc. – this faculty group has become the students' best advisor. The faculty are more intimately involved with the students than is generally the case in a departmental structure. From these meetings all the faculty have a better understanding of the program and the integration of the students' education. The faculty also has a better understanding of all the courses a student takes and how each contributes to the whole program. Furthermore, the continuous dialogue at the meetings has made us realize that we are in fact accomplishing an ongoing assessment process, not only for student issues but also for the overall program.

Recommendations and Summary

We believe that implementation of multidiscipline engineering programs and curriculum reform, started in response to requests by industry leaders and recommendations by government agencies, including the National Science Foundation, are the trend for future engineering programs. However, it may not be possible to accomplish everything within the traditional four year timeframe. This paper compared a five year Electromechanical Engineering program at Wentworth Institute of Technology with traditional four year Electrical and Mechanical Engineering programs at another institution. The conclusion is, the addition of one more academic year to a classic four-year program delivers to the student the equivalent coursework of a second single-discipline engineering degree. This is a surprising result, and in fact we believe it is the new academic model for engineering education in the future. As faculty begin to develop and implement nontraditional or multidisciplinary engineering programs, we recommend at least two major considerations: faculty buy-in and administrative support.

Faculty buy-in

In order to oversee such programs, a committee structure which brings together the talents of faculty from different disciplines is required. The best faculty for such a program committee structure are those who willingly volunteer and understand how it differs from a departmental structure. Faculty must be willing to develop the entire program and determine how each course is intended to strengthen the program's mission and objectives. Therefore, faculty may have to change their individual course or courses if it is in the best interests of the program. Faculty must

also be willing to work in a committee structure and build a culture that complements the institution, the program, and the students. Finally, faculty must be willing to take ownership of the program and not expect that someone else will be responsible for the work.

Four reasons that have been articulated by the faculty for a committee structure are: (1) a culture develops among the faculty that does not exist in the department; (2) the committee has a built-in cohesion and leadership while the department structure is only a management structure; (3) there is greater faculty collaboration – faculty think of the program first and not individual courses; and (4) faculty have a greater stake and commitment to the students and the success of the program.

Administration support

Administrators must be willing to encourage faculty to operate outside the traditional department structure, yet be willing to provide them their own physical location (if possible) and financial assistance when needed. Administrators must understand and be willing to adopt a bottom-up approach that can create different learning environments that encourage team-teaching and learning among similar and support disciplines, including the general education component.