

Synergy Approach to a New Mechanical Engineering Degree Program

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Abstract—USM is graduating its first mechanical engineering class in May of 2009. That is 21 years after the Department of Engineering was formed to deliver electrical engineering as its only degree program. Introducing a new degree program with minimum start-up costs has been possible by 1) synergy with the existing degree program, 2) sharing faculty, administration, facilities and equipment available in the department, and 3) leveraging adjunct faculty, peer facilities and some distance education. A novel BSME program emerged, a degree that focuses on electromechanical systems as recommended by our industrial partners. We developed an integrated curriculum, where only one fifth of the total number of credits is required exclusively by one degree or another. Enrollments in the new degree program are increasing to the point where we are now able to self-support additional faculty lines. A tenure-track faculty search is underway. This effort provides a blueprint for future expansions at our own academic unit and at other small institutions facing similar resource constraints.

I. INTRODUCTION

The University of Southern Maine is a public, regional, urban, comprehensive institution. USM is committed to delivering a wide range of mostly undergraduate and professional programs, serving primarily the Greater Portland area, the population and industrial center of the State of Maine. In contrast, the University of Maine is the land-grant institution in the state. UMaine has a large College of Engineering, offering a full range of graduate programs, but it is located in Orono, nearly 150 miles north of Portland, in a rural and sparsely populated area of the state.

Up to the mid-1980s, attempts were made by UMaine to bring engineering education to the Greater Portland area. Those efforts failed not just because of the physical distance involved, but perhaps primarily because of a mismatch between the core mission of UMaine and the significant population of non-traditional students seeking college degrees in the south. USM had not only the benefit of geography, but also the experience of serving the urban student population. Many of our students require a flexible schedule with evening courses, classes that are longer and less frequent, and a slower pace of degree progress.

The USM Engineering Department was formed in 1988, with heavy support from local industry, to deliver a Bachelor of Science in Electrical Engineering (EE) degree program. It was anticipated that other engineering programs would be added later under the same academic unit, thus the generic

department name. ABET accreditation was granted in 1992. Enrollment in the program has remained relatively stable at around 100 students for two decades. We offer a transfer program for students interested in continuing their education in other engineering disciplines at UMaine or elsewhere, but there has been limited interest in the transfer program by the student population. A minor in electrical engineering was also established, but it had no enrollment. As originally conceived, the minor was never attractive because requirements were too extensive for a non-major to take advantage of. Realistically, engineering minors are attractive almost exclusively to students of other engineering disciplines, because only they could share the math and science prerequisites for the mid-level courses that comprised the minor without a significant additional undertaking. Having a single engineering program denied our students that opportunity, and denied us the benefit of additional enrollments. We concluded that developing new engineering programs at USM was essential for a sustainable growth in numbers and in opportunities, both for students and for faculty.

Several curriculum and program initiatives were implemented in the early 2000s. The EE minor was streamlined, a concentration in computer engineering was introduced as a separate track within the EE program, and computer engineering became an emphasis of the Master of Science in Computer Science that is jointly delivered with our peer department. Those initiatives resulted in more opportunities, but modest growth. The significant leap forward we were waiting for finally happened in 2006, when the Board of Trustees approved the Bachelor of Science in Mechanical Engineering (ME) degree program. We discussed the challenges before us to develop a program with limited resources last year [1]. This paper takes the next step and discusses the curriculum approach to the new degree and how it leveraged the resources from our existing EE program.

II. A NEW DIRECTION

One of the conditions for approval of the new degree program was that we would leverage existing resources (faculty, administration, facilities, equipment) to the extent possible so as to incur in minimum start-up costs. But saving money was not our sole motivation. After surveying our industrial partners and supporters in 2001, we learned that southern Maine engineering companies were not just interested

in another ME degree program, one that was more accessible to their present and future workforce. They were in need of a different kind of mechanical engineer; an engineer with a strong background in electromechanical systems, something that traditional ME programs do not typically offer. Our experience delivering electrical engineering for 20 years uniquely positioned us to design such a degree program in a manner that would be jointly delivered under a single existing academic unit.

Our new integrated curriculum includes an engineering core, containing several courses that were already in place for the EE program (Fig. 1). But designing the new degree wasn't as simple as adding existing courses to the new requirements, because some of the courses had to change in order to serve both degrees. The most salient change was in the area of circuits. EE programs typically include 2 semesters of circuits at the sophomore level. Traditional ME programs require only one semester of circuits, often in the form of a dedicated, streamlined course, separate from those delivered to EE majors. When ME students study systems and control later, they apply some of the same mathematical tools that a full year electric circuits sequence does, such as ordinary differential equations and the Laplace transform. It would not have been cost effective for us to develop separate tracks to deliver such similar content. Our solution was to transform the sophomore circuits sequence to serve both degrees.

As we reviewed the delivery of circuits, we noted that we usually split the sequence into time-domain analysis in the first semester and frequency-domain in the second. The first semester begins with network analysis in DC and ends with second-order transients. The second begins with sinusoidal steady-state analysis and AC power, and moves on to frequency response and Laplace. This approach has the disadvantage that sophomore students must work on solving ordinary differential equations in the fall semester; one semester before they take differential equations from the math department. Electrical engineering faculty often argue that there is so much to cover, with electronics coming up in the junior year, that we can't afford to wait that long. At the same time, AC power seemed out of place in the second semester because the analysis is based on a single, constant frequency – not quite “frequency domain.” The transformation offered us the opportunity to address those issues.

The solution proposed was to recast the first semester of circuits as a steady-state analysis course (*ELE 216-Circuits I: Steady-State Analysis*), bringing AC power in and leaving transients out. It remained a basic electrical engineering circuits course, though, as most institutions require for an ME degree. The second semester, on the other hand, saw more significant changes. We focus on the solution to ordinary differential equations, first in the time domain, then in the frequency domain using Laplace, in a manner that runs parallel with the differential equations course that our students take from the math department, but applying the concepts to the

behavior of electrical, mechanical, fluid and thermal systems. This is recognized by mechanical engineers as system dynamics, going back to the work of J. Lowen Shearer at Pennsylvania State University in the 1960s [2]. Electrical engineers are not usually exposed to that perspective.

This curricular approach became a win-win innovation for us. ME students are served without duplication of classes, while EE students gain transferable skills to model any dynamic system, be it electrical, mechanical, fluid, thermal or any combinations thereof. But unlike the mechanical engineering approach to system dynamics, which naturally relies on the mechanical model as a starting point [3, 4, 5], we start with the electrical model. For that reason, we haven't removed the word “circuits” from the course title (*ELE 217-Circuits II: System Dynamics*). It makes sense for us because the laboratory experience that is integrated with the course is circuits-based. Course catalog descriptions are included for reference in the Appendix. Our complete catalog is available in [6].

III. COMMON BACKGROUND FOR ADVANCED COURSES

Having acquired the necessary background in circuits, our ME students take *ELE 323-Electromechanical Energy Conversion* in the junior year, together with our EE students. Therefore, they are exposed to 3-phase power, transformers and electric machinery (motors and generators). This requirement advances the program mission of a mechanical engineering degree with electromechanical focus. Each one of these courses, from circuits to electric machinery, is delivered with an integrated laboratory component. Students in those classes gain experience with devices, instrumentation and equipment, and practice working in interdisciplinary groups.

The breadth of specialties that an engineering discipline comprises can not be covered by required courses alone. Otherwise, the number of credit hours would increase to an unreasonable level for a 4-year baccalaureate degree. The engineering curriculum at USM requires four technical electives at the upper-division level (junior and senior) from an array of topics that are offered on a 2-year rotation basis. The common background in “circuits/system dynamics” enables ME students to take advantage of several established technical electives in robotics, controls, MEMS and others. Conversely, EE students may take some of the mechanical engineering electives that have been introduced, such as vibrations. For a small department like ours, broad access to technical electives is essential to maintain viable enrollments. More must be said about control theory, though. Being a technical elective, only a fraction of the students take it. However, our industrial partners have identified controls as an important skill set for both electrical and mechanical engineers that they hire. Therefore, we incorporated basic principles of feedback and stability at the end of *ELE 217*, ensuring that all of our graduates have at least a basic understanding of control theory.

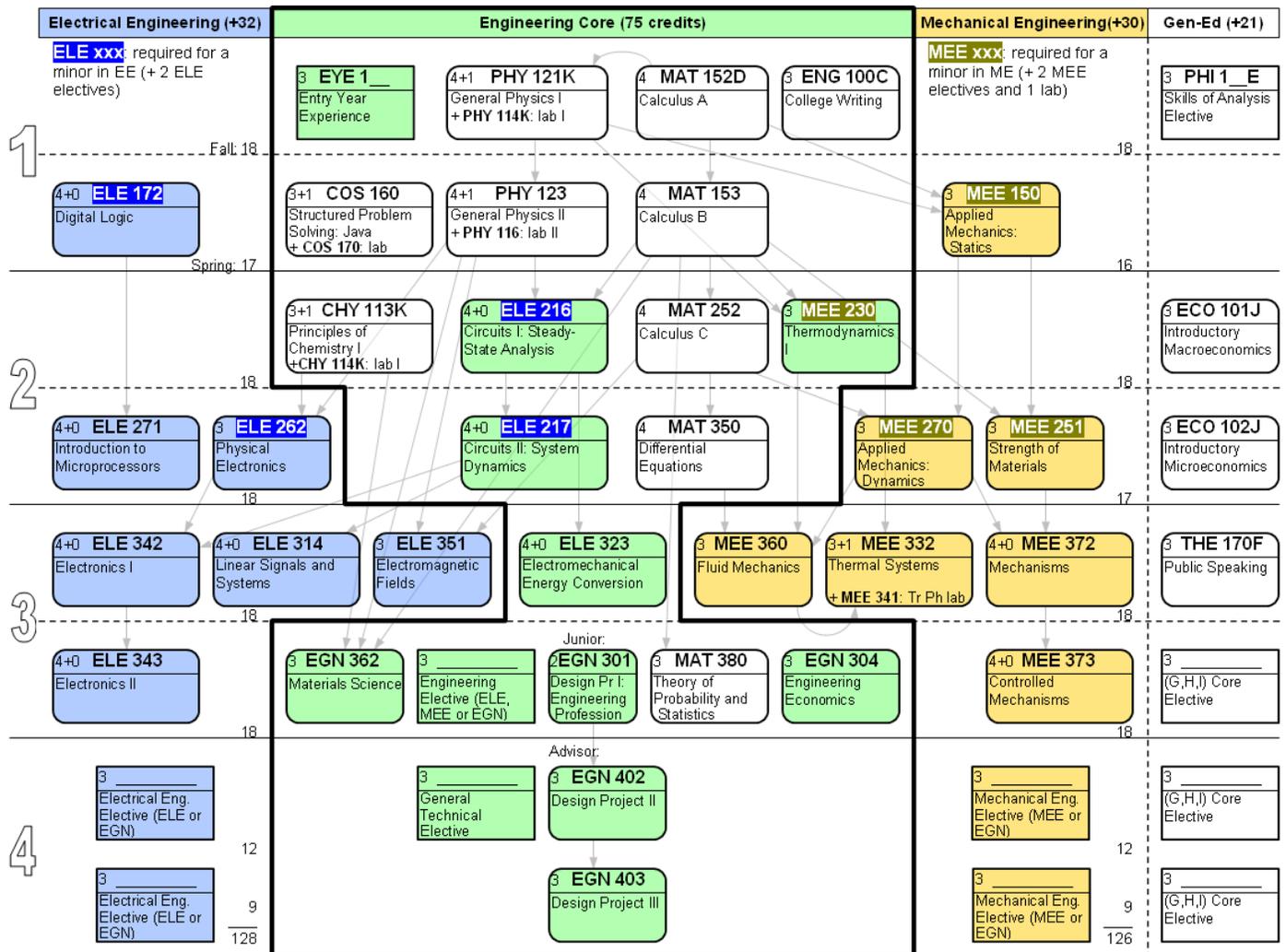


Fig. 1. USM Engineering – 2009/2010 Integrated Curriculum. Each block represents a course, with the noted number of credits. A laboratory component is either integrated into the course (noted as a +0 for credits) or a separate, concurrent course (noted as a +1). Arrows represent prerequisites.

In a typical engineering program, all required courses in the curriculum are offered at least once every year. However, in order to bridge the resource gap between the introduction of the new ME program and the hiring of full-time faculty to deliver much of its content, we studied the inclusion of some required courses in the 2-year rotation as an interim measure. The plan resulted in a total of 7 upper-division required courses, namely *ELE 271*, *ELE 314*, *ELE 343*, *ELE 351*, *MEE 332*, *MEE 360* and *MEE 373*, that are offered once every 2 years. We call those courses “terminal,” meaning that they are not prerequisites to any required course in the curriculum. The rotation still allows a traditional student in either program to graduate in 4 years, but not without careful advance planning with his/her academic advisor.

There are opportunities lost, however, as some students are not able to take certain technical electives for lack of prerequisites. For example, *ELE 343-Electronics II* is part of the 2-year rotation and a prerequisite for the technical elective *ELE 444-Analog Integrated Circuits and Design*. Because of rotation, half of the EE students will take *ELE 343* in the

spring of 4th year – the last semester for a traditional student. Those students who may be interested in taking *ELE 444* will have to either take it in the fall of their 5th year or graduate without it.

As we studied the rotation plan, we also reexamined the delivery of evening courses to serve our non-traditional students. The result is a rotation where all required engineering courses are offered in the evening once every 4 years. The rotation is such that traditional students are not overburdened by being required to take more than one evening course in any given semester. They take no more than 5 evening courses during the entire 4-year program. On the other hand, non-traditional students who can’t take engineering classes during the day are now able to take up to 2 engineering courses in the evening every semester. They are able to graduate in 7 to 9 years, depending on the matriculation date. This timeframe is compatible with the aspirations of the non-traditional students we serve. The full rotation plan has been approved by the department and is currently in its second year of implementation.

Other transformations affecting our curriculum are happening at USM. The university is in the process of introducing a new general education curriculum and phasing-out the current one that has been in effect since 1982 [7]. This transformation must be an integral component of our planning because gen-ed encompasses nearly one third of the entire curriculum. The current gen-ed is based on satisfying a collection of isolated requirements in English, Mathematics, Philosophy, Performing Arts, Fine Arts, Literature, History, Social Sciences, and Natural Sciences, all at the introductory level. We call it a horizontal approach. In contrast, the new gen-ed that is being developed is intended to be vertical, with requirements to be met at every level of the student degree progress. Our senior design project experience has inspired the new gen-ed development; it now includes a university-wide capstone requirement. Our integrated curriculum is well prepared to incorporate the gen-ed transition. Any new gen-ed requirements will be placed in the engineering core, and we will in fact participate in the delivery of some of the courses.

IV. CURRICULUM

Fig. 1 captures our integrated curriculum. The engineering core is shown in the center, boxed under a green header, running vertically from the first through the fourth year. It consists of 75 credits of courses that are common to both programs. Courses colored green, such as circuits and thermodynamics, are delivered by engineering faculty and range between 29 and 38 credits, depending on the choice of electives. White courses, such as math and physics, are common courses outside of engineering. Courses that are only in the mechanical engineering program are colored gold, adding 30 credits. Courses that are only in the electrical engineering program are colored blue, adding 32 credits.

Completing the curriculum, the gen-ed requirements are listed on the far-right (those that are not yet part of the engineering core) for an additional 21 credits. The total number of credits required to graduate is 126 for the ME degree and 128 for the EE degree. As the new gen-ed requirements are refined and approved, the Gen-Ed column will be replaced by new courses inside the engineering core.

The requirements for a minor in either electrical or mechanical engineering are noted in the form of highlighted course codes and an explanation at the top. A student may get a minor or a double major with minimum additional credits by choosing certain technical electives for maximum double-dipping. An ME student needs 7 additional credits (2 classes) to get a minor in EE and 13 more (3 classes) to graduate with EE as a double major. An EE student needs 9 additional credits (3 classes) to get a minor in ME and 9 more (2 classes) to graduate with ME a double major. Ending the progression, a student may earn the 150 credits needed for a second degree by taking 4 additional credits.

The four technical electives required by either degree program are such that a student must complete two in his/her

own major. The other two may cross over into another engineering discipline, and one may even be from outside of engineering. But because some technical electives are dual-discipline courses, such as robotics and controls, the minimum number of credits for the EE program that is exclusively in electrical engineering is 26, or 20% of the total required for graduation. The minimum number of credits for the ME program that is exclusively in mechanical engineering is 24, or 19% of the total. The relatively small number of courses delivered exclusively for the new ME degree (7 courses, plus electives) has enabled us to start the program without immediately adding new faculty. Table I provides an approximate distribution of content in either program, in terms of a percentage of the total number of credits.

TABLE I
USM CURRICULUM DISTRIBUTION - OUTSIDE VS. INSIDE ENGINEERING

Humanities	20%	Core	30%
Math and Science	20%	Discipline-Specific	20%
		Technical Electives	10%
Total Outside	40%	Total Inside	60%

V. RESOURCES

Access to adequate facilities plays a central role in the implementation of a new engineering degree program. Many laboratory facilities are shared between the two programs, most notably in circuits, electric machinery and robotics. But new equipment and space were still required to enable us to deliver the new degree, in areas such as fluid mechanics, strength of materials and mechanical design. The Technology Department, which is housed in the same building as the Engineering Department, has provided access to an extensive machine shop, a CAD and rapid prototyping laboratory, an automation laboratory and a mechanical, pneumatic and hydraulic power laboratory. We also share the staff support of a laboratory associate and a manager of computer technology. In addition, the expansion of the building, made possible through a combination of federal, state and private funds, provided space and equipment for a new mechanical engineering laboratory.

In order for synergy between the two programs to be effective, students must welcome the idea. That was the easiest part, as our students are eager to collaborate with each other. Each program supports its own professional society student group, namely the IEEE and the ASME. Yet students from both programs join forces to organize technical tours to local engineering companies, volunteer to promote the department and the school, and engage in a variety of social activities. Several senior project teams are interdisciplinary, which is excellent training for the environment they will enter in their professional careers.

The next challenge we face is to build teaching capacity. Thus far, we have delivered both programs with 6 existing full-time engineering faculty. All faculty were initially hired to teach electrical engineering, but some also have a mechanical

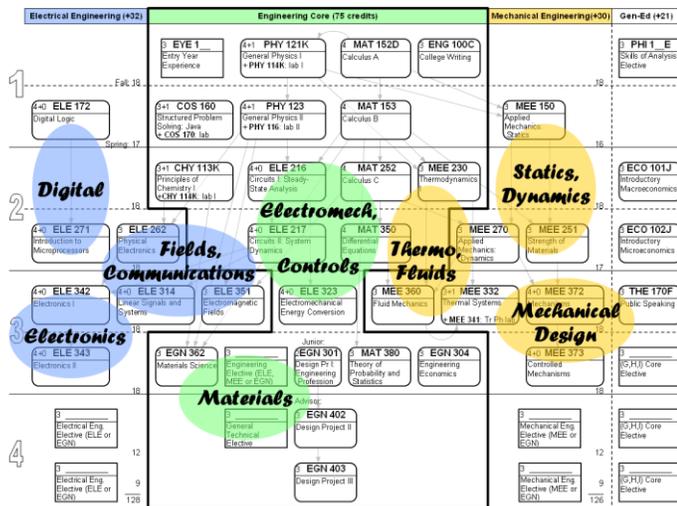


Fig. 2. USM Engineering – Eight areas of faculty expertise: 3 in Electrical Engineering, 3 in Mechanical Engineering, and 2 that are common to both disciplines.

engineering background. The capacity is being supplemented during this build-up phase by adjuncts from the local engineering community and by some distance education from UMaine.

The previous section presented the curriculum from the student point of view. Fig. 2 presents a version of the curriculum from the faculty expertise point of view. Based on both expertise and teaching load, we conclude that we require a minimum of 8 full-time faculty to deliver both programs, or 2 additional faculty lines from our present state. A search is underway for our first full-time mechanical engineering faculty. It takes a special kind of faculty to teach a variety of topics, many on a 2-year rotation basis, often crossing over between disciplines, and to do it well. We seek to hire new faculty who share this attitude and aptitude.

VI. CONCLUSION

USM will graduate its first mechanical engineers in May of 2009. Double-majors and minors in both disciplines are increasing with each passing year. We now support approximately 60 ME students and 100 EE students, and we hope to approach 200 students in a few years. A recent study has stressed the value of small engineering schools for the United States workforce, since small schools graduate one quarter of all new engineers in the country and employ one third of the faculty [8]. Once our resources are in place, we will be well positioned to consider another leap into a new degree program. This effort provides a blueprint for future expansions at our own academic unit and at other small institutions facing similar resource constraints.

APPENDIX: CATALOG DESCRIPTION OF SELECT COURSES

ELE 216 Circuits I: Steady-State Analysis

An examination of fundamental circuit laws and theorems, network analysis, physical properties and modeling of resistors, inductors, and

capacitors. Sinusoidal steady-state operation, phasors, impedance, power, three-phase systems, and the ideal transformer. The course also covers the operation of meters, oscilloscopes, power supplies, and signal generators.
Prerequisites: MAT 153, PHY 123. Lecture 3 hrs., Lab. 2 hrs. Cr 4.

ELE 217 Circuits II: System Dynamics

Time-domain analysis of first- and second-order systems, based on electric circuits, but drawing analogy to mechanical, fluid, and thermal systems. Study and application of the Laplace transform for the solution of differential equations governing dynamic systems. Frequency domain analysis, transfer functions, poles and zeros, frequency response, basic filtering, and resonance. Principles of control, feedback, and stability.
Prerequisite: ELE 216. Lecture 3 hrs., Lab. 2 hrs. Cr 4.

ELE 323 Electromechanical Energy Conversion

Basic concepts of magnetic circuits and transformers. Three-phase system and power transmission. Conversion between electrical and mechanical energy through magnetic fields. Study of direct current motors and generators. Study of alternating current machines: induction motors, synchronous machines, and single-phase motors.
Prerequisite: ELE 216. Lecture 3 hrs., Lab. 2 hrs. Cr 4.

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