

EE and ME – Together Again: Forging a BSE from BSEE and BSME Programs

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Abstract

An unfortunate premise is that neither the undergraduate Electrical Engineering (EE) nor the Mechanical Engineering (ME) degree programs can accommodate within their curriculum substantive EE or ME courses. Yet there is a natural intersection between EE and ME for professional opportunities in the 21st century. To break this seeming impasse a program of study between EE and ME has been initiated as one aspect of an Interdisciplinary Engineering (BSE) degree with plans of study for Electromechanical Engineering and Energy and Power Engineering at Temple University. Only existing courses in EE and ME were integrated into these plans of study for the BSE degree. The BSE program utilizes no new courses, requires no new faculty and only administrative resources. Interdisciplinary design objectives were promoted and utilized in discipline undergraduate course laboratories and the capstone design project for these students. The BSE program is uniquely administered by the College and not by a Department and has a Director and not a Chair.

Introduction

The Electrical Engineering (EE) discipline was once embellished with a significant number of Mechanical Engineering (ME) courses suitable for between-the-world-wars technical training.¹ Even as late as the 1960s EE students were required to take ME courses in statics, dynamics, nature and properties of materials, and thermodynamics.² Although the 1960s was the incipient age of solid-state electronics, EE students also took compulsory courses in electric machinery and power transmission.

The rapid development of digital logic integrated circuits and the microprocessor in the 1970s shifted the extent of the EE curriculum away from these courses. Accelerating the shift were new topics such as microelectronics, probability and statistics, digital signal and image processing, and digital communications and control. The result is that most, if not all, EE curricula today do not feature any substantive required courses in ME.³

The Mechanical Engineering (ME) discipline often requires a single course and laboratory in direct and alternating electrical circuits, electrical power and analog and digital electronics. Subsequent elective courses in the ME discipline may include sensor integration and processing as mechatronics and electromechanical machinery. The result is again that most, if not all ME curricula, today do not feature any substantive courses in EE.³

Presented here are the refinements for the developmental path of an interdisciplinary BSE program between existing BSEE and BSME programs.^{4,7} The resulting integrated undergraduate curriculum, course and capstone design projects, the observed and assessed progress to date from its concept and inception⁴ and the pitfalls to be avoided are presented. Survey results of the constituents of the BSE program are discussed and the professional employment and facilitation

of graduate study is described for the cadre of students over the previous five years from 2012-2017.⁴

Development of an Interdisciplinary Program

The integration of courses from another engineering discipline into an undergraduate degree program seems to be fraught with difficulties. The faculty from each discipline is concerned that requisite courses define the degree program and that other courses can only be approved electives. Although a typical discipline curriculum could include as many as three engineering elective courses, the advising suggestion that seemingly predominates for such elective courses is to take only those from the discipline. This is especially endemic when preparatory and prerequisite courses are considered within an engineering degree program.

EE courses such as electromechanical systems and power generation and transmission require an EE degree course in electromagnetics and transmission lines. ME courses such as heat and mass transfer and renewable and alternative energy require ME degree courses in dynamics, the mechanics of solids and fluids and thermodynamics. Thus, within the confines and restrictions of the available engineering discipline elective courses there is no opportunity for effective interdisciplinary undergraduate study. The solution proffered here is an interdisciplinary engineering degree program that can cross these barriers.

ABET baccalaureate accreditation provides Criteria for Engineering, Engineering Physics, Engineering Science and General Engineering programs. After review, consideration and discussion the College sought a BSE program under the Engineering Criteria. This provides identification of the BSE program that is not in conflict with existing engineering discipline degree programs.

Engineering Criteria degree programs are often appropriately situated at smaller institutions that do not offer engineering discipline degree programs or, as is sometimes the case, at larger institutions with multiple engineering discipline degree programs. In the former case, the programs provide, as the name indicates, a creditable engineering education but not in a discipline. In the latter case, these degree programs seem to be lost in the torrent of engineering discipline degree programs. On occasion, worst yet, they are not even accredited or are promoted somewhat despairingly by the institution.

This Engineering designation seems to resonate well with the concept of interdisciplinary study and engenders the necessary cooperation from the established engineering departments of the College. The program is identified as Interdisciplinary Engineering (BSE) with a common freshman and capstone senior design curriculum as in the other engineering discipline degree programs in the College.

The clarion call for interdisciplinary engineering by educators has been sounded before.^{5,6} What may be different now is that potential employers, simply put in one example, recognize the utility of hiring two electromechanical engineers rather than an electrical and a mechanical engineer.⁶ This sentiment is even shared by the Industrial Advisory Committees of the BSEE and the BSME programs of the College of Engineering at Temple University for these focused areas.

Interdisciplinary Program Administration

Although such engineering programs are sometimes offered in a separate academic department, this interdisciplinary BSE program was established with a Director and administered in the College of Engineering. The Director has the responsibility to ensure that all aspects of the program, including continuous improvement of the curriculum, are ensured.

The Director is also the single interface between the students and government, military and industry for co-operative work study assignments, internships, capstone design projects and professional employment. The appointment of a designated Director assures that the interdisciplinary BSE program maintains visibility and credibility within the College.

The Director, who currently is an EE faculty member, and faculty advisors from both EE and ME provide support for appropriate course selection, seamless integration and continuing professional development. This was important for success because there were a significant number of transfers by undergraduate students from both the BSEE and BSME programs to the BSE program after the interdisciplinary BSE program was promulgated.

Interdisciplinary Curriculum

The curriculum for the BSE program features a common freshman year with the BSEE and BSME programs. Students are advised throughout their first two semesters of all the degree programs available in the College and make a selection at that point.

The core curriculum for all degree programs in the College includes mathematics and basic science, social sciences, humanities and communication courses, introduction to engineering and the capstone senior design sequence. Unique to the BSE program though are requisite courses in macroeconomics, engineering economics and human resource management.

Only existing courses in EE and ME were integrated into the plans of study in the BSE program. All discipline course prerequisites are satisfied with no exceptions. This assures compliance with the criteria for accredited Engineering baccalaureate programs and utilization of existing assessment activities for the program educational objectives and student outcomes. Two of the BSE program interdisciplinary plans of study are in Electromechanical Engineering and Energy and Power Engineering.

There are currently three other interdisciplinary plans of study for the BSE program which include Electro-Optical Engineering with Physics, Hardware and Software Engineering with Computer Science and Engineering Fundamentals which engages the entire College with its four academic departments, including Civil and Environmental Engineering and a newly established Department of Bioengineering.

All degree programs in the College feature a common freshman year focusing on the profession, preparatory skills and retention. A new innovation is the Chemistry for Engineers course, a science course concerned with topics for professional development. GenEd is the University core requirement which satisfies the social sciences and humanities requirement.

First Semester

Calculus I
Chemistry for Engineers, Chemistry Lab
Introduction to Engineering
GenEd Analytical Reading and Writing

Second Semester

Calculus II
Elementary Classical Physics I
Engineering Graphics
Computer Programming and Analysis
GenEd Humanities I

Plan of Study in Electromechanical Engineering

The BSE program plan of study in Electromechanical Engineering (EME) emphasizes all aspects of electromagnetics, transducers, sensors, electronics, digital processing and mechanical principles to integrate these components into electromechanical devices and systems for automated manufacturing processes. Professional employment includes the analysis, design and installation of robotics and automation for diverse industries.

ME courses in this plan of study follow the thread of graphics, statics, dynamics, the mechanics of solids, dynamic systems and machine theory and design. EE courses follow the thread of computer programming, digital design, circuits, electronics, electromagnetics, electromechanical systems and microprocessor systems.

Two engineering electives provide the opportunity for further interdisciplinary study with the prerequisites in both EE and ME having been satisfied. The curriculum for the BSE EME program plan of study is as follows:

Third Semester

Calculus III
Elementary Classical Physics II
Engineering Statics
Electric Circuits
Technical Communications

Fourth Semester

Differential Equations
Engineering Dynamics
Digital Circuit Design and Lab
Electric Circuits Lab
GenEd Humanities II

Fifth Semester

Introduction to Electromagnetic Fields
Processor Systems and Lab
Engineering Analysis and Applications
Macroeconomic Principles
GenEd Human Behavior

Sixth Semester

Electromechanical Energy Systems
Mechanics of Solids
Dynamic Mechanical Systems
Engineering Seminar
GenEd Race and Diversity

Seventh Semester

Senior Design Project I
Machine Theory and Design
Engineering Economic Analysis
Engineering Approved Elective
GenEd World Society

Eighth Semester

Senior Design Project II
Engineering Approved Elective
Human Resource Management
GenEd The Arts
Free Elective

Plan of Study in Energy and Power Engineering

The BSE program plan of study in Energy and Power Engineering (EPE) emphasizes all aspects of electrical power and mechanical energy innovation in energy generation and delivery, alternative resources, and efficient devices. Professional employment includes the control of large utility system energy and transmission, and the design and deployment of alternative energy sources.

ME courses in this plan of study follow the thread of statics, dynamics, thermodynamics, dynamic systems and renewable and alternative energy. EE courses follow the thread of computer programming, circuits, electronics, electromagnetics, electromechanical systems, power engineering and electronics, and photovoltaic components.

Although the BSME program has an Energy Systems concentration this BSE program plan of study in Energy and Power is more expansive and incorporates electromagnetics, electromechanical energy systems, and power engineering and electronics from the BSEE program.

Three engineering electives provide the opportunity for further interdisciplinary study with the prerequisites in both EE and ME having been satisfied. The curriculum for the BSE EPE program plan of study is as follows:

Third Semester

Calculus III
Elementary Classical Physics II
Engineering Statics
Electric Circuits
Technical Communications

Fourth Semester

Differential Equations
Classical and Statistical Thermodynamics
Engineering Dynamics
Electric Circuits Lab
GenEd Humanities II

Fifth Semester

Introduction to Electromagnetic Fields
Engineering Analysis and Applications
Engineering Approved Elective
Macroeconomic Principles
GenEd Human Behavior

Sixth Semester

Electromechanical Energy Sys and Lab
Dynamic Mechanical Systems
Engineering Approved Elective
Engineering Seminar
GenEd Race and Diversity

Seventh Semester

Senior Design Project I
Power Engineering and Electronics
Renewable and Alternative Energy
Engineering Economic Analysis
GenEd World Society

Eighth Semester

Senior Design Project II
Engineering Approved Elective
Human Resource Management
GenEd The Arts
Free Elective

Pitfalls and Successes

The basic concept of interdisciplinary engineering study, especially between the naturally related subdisciplines of EE and ME in electromechanics and energy and power, is not unique.⁸ Unfortunately, nurturing such an interdisciplinary BSE program can be more problematic.

One pitfall seems to be the establishment of a separate academic department to administer the BSE program. This usually engenders the inevitable conflict for resources. Here the BSE program is administered in the College, utilizes only existing courses and faculty, and requires only separate administrative resources. The BSE program Director consults regularly on academic concerns with the BSEE and BSME program Directors who are also Chairs of their discipline departments. The Director of the BSE program is in this sense an intermediary and can focus on pedagogical and not departmental concerns.

Interdisciplinary degree programs with a variety of models of execution have been studied in research in engineering education.^{9, 10, 11} The developing perceptions of undergraduate students in an interdisciplinary engineering curriculum are significant to the overall success of the degree program.¹⁰

Design in the Interdisciplinary Program

The issue of appropriate laboratory and design projects within an existing EE or ME course, originally designed for those discipline students, may be an issue for the BSE student. Since they have the course and laboratory prerequisites within that discipline, satisfactory performance in the laboratory is expected, but is that *good enough*?

However, this disparity is being addressed as the enrolled cadre of BSE students increases. New design and laboratory projects suitable for their interdisciplinary preparation in these discipline courses are being developed by the BSE program Director with the cooperation of the responsible faculty in EE and ME.

However, the demonstrable success is in the capstone senior design sequence. Particular teams composed of EE, ME or EE and ME students have been indirectly assessed to have augmented performance by the inclusion of BSE students on interdisciplinary projects.

The existence of an interdisciplinary BSE program can also be the impetus for a sea change which can benefit all engineering programs. Further research in engineering education has identified perhaps the key barriers to interdisciplinary study.⁹ Students apparently lack the ability to provide the salient connections between and understanding of the contributions of various disciplines. Yet the BSE student could provide a peer role model of interdisciplinary understanding in engineering practice.

As a direct result of this sea change, a new *ME for EEs* course, actually termed *Mechanical Systems*, as a requisite for all EE students has been offered because of the discussions on the implications of the interdisciplinary engineering curriculum by the EE faculty.³ Infusing

mechanics into such EE courses as electromechanical systems, control theory and electrical power and energy conversion had been challenging without the inclusion of this *ME for EEs* course.

Professional Careers and Graduate Education

Of course, the Electromechanical Engineering (EME) and Energy and Power Engineering (EPE) BSE programs are not meant to be the strict equivalent of the defined discipline BSEE and BSME programs, nor should they be. However, for professional careers in the areas addressed specifically by these programs the prospects for employment and success can be arguably presented and demonstrated to be quite reasonable. BSEE and BSME students, although well prepared within the disciplines, are not equipped with the basic tools needed to, in an often heard employment mantra, *hit the ground running* in interdisciplinary EME and EPE applications.⁶

Further engineering study for these students in the EME and EPE BSE programs could certainly include additional undergraduate and graduate courses in EE and ME since they have had the prerequisites courses in the respective disciplines. It does seem somewhat incongruous to expect a post-baccalaureate engineering student to take graduate courses in a discipline for which she or he has no undergraduate precedent.

Recruitment of Students

With the curricular structure in the EME and EPE BSE degree plans of study in which only existing EE and ME courses are utilized, the program seems to exhibit no unreasonable constraint on attracting students. Recent freshman enrollment data in the College show that entering students have selected the plans of study in the interdisciplinary BSE program on par with the discipline engineering programs.

This is a somewhat startling and unexpected result. In interviews and surveys of these freshmen, the reason seems to be the attraction of programs with names for the plans of study that are non-traditional and with defined professional employment.

Assessment

Following the plan outlined by other studies in engineering education, the programmatic assessment of this interdisciplinary approach can be marked by tangible results.^{9, 12} These include current internships and co-operative education assignments in electromechanics and energy and power and in improvement in the performance of interdisciplinary capstone senior design projects.

Indirect assessment from exit surveys upon graduation by BSE students also provide relevant input to the continuous improvement of the program. An example of three exit survey questions and responses indicate general approval of the BSE program and its curriculum.

Are you satisfied with the courses taken in Business and Management and Engineering Economics?

“No other engineering degree in the College has the chance to take such courses and have them on the resume.” “These courses were noted in my employment interview and got me the job.” “Why doesn’t EE and ME have such courses?”

Are you satisfied with the advising for engineering electives you studied?

“The advice I got was exactly what I wanted to do.” “Because I had the prerequisites I was able to take additional EE courses which will help me in my job.” “There were many possibilities but the advice I got allowed me to consider the alternatives.”

Are you satisfied with the advising you received for post-baccalaureate education?

“I never really considered going for a Master’s degree but with the interdisciplinary courses I have I am now.” “I will be taking cross-listed technical electives that will start me toward a Master’s.”

Relationships with targeted industries, the military and government agencies are also seemingly enhanced. Survey responses of the student constituents are overwhelmingly positive to date since their career aspirations are clearly defined by the EME and EPE plans of study. Employers as constituents also are keen to embrace this new paradigm and recognized, for their specific concerns, a profound shift in undergraduate engineering education.

The imperative call for interdisciplinary projects in the capstone senior design project from past experience meant bringing together EE and ME students on a team. Unfortunately, the barrier to interdisciplinary applications is usually quite evident in the performance of those teams across the engineering disciplines.¹⁰ Current indications by indirect assessment are that students in the BSE program are well suited to contribute to focused design projects in electromechanics and energy and power.

Undergraduate courses in the BSEE and BSME programs, which are the salient course constituents of the interdisciplinary BSE program, are directly and indirectly assessed as part of the ABET accreditation process utilizing AEFIS (www.aefis.com). AEFIS provides course evaluations, surveys and outcome alignment common to both the BSEE and BSME programs.

The Director participates in the review of the course performance as part of continuous improvement. The BSE program was also presented to external consultants as part of the Periodic Review process at Temple University in 2016 and the results were very satisfactory.

But What Does an Interdisciplinary BSE Program Require?

The College is committed to the continuing development of the interdisciplinary BSE program because it requires no additional resources yet affords another opportunity for students to excel and meet the demands of professional employment. The three requisite courses in macroeconomics, engineering economics and human resource management again differentiate the BSE program within the College and resonate well with potential employers.

However, without the support of a college administration and the affected academic departments an interdisciplinary BSE program between EE and ME will simply not prosper. The BSE program has by design only administrative resources and requires the co-operation of the EE and ME faculty and the office of undergraduate studies of the college.

Promotion of interdisciplinary engineering study to the constituents of the program, both students and employers, must also be evident from the faculty advisers of the EE and ME disciplinary programs. This is only reasonable since faculty certainly desire that our students be well prepared to face the engineering challenges of the 21st century. An interdisciplinary BSE program between EE and ME is another reasonable manner by which that can be accomplished.

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