

EE and ME – Together Again: Electromechanical and Energy and Power Engineering

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Introduction

An unfortunate and continuing premise is that neither the undergraduate Electrical Engineering (EE) nor the Mechanical Engineering (ME) degree programs can accommodate within their curricula a substantive sequence of EE or ME courses. This is predicated because the EE and ME disciplines seem to be rigid within their threads, prerequisites, and electives. Yet there is a natural intersection between EE and ME for continued professional opportunities in the 21st century.

To break this seeming impasse an interdisciplinary program between EE and ME had been initiated as an Engineering (BSE) degree in 2012, received accreditation in 2018 and in 2020 obtained academic concentrations in Electromechanical Engineering (EME) and Energy and Power Engineering (EPE). The BSE EME and EPE programs resides in the new Department of Engineering, Technology, and Management (ETM) in the College of Engineering at Temple University, rather than within either the EE or ME Departments.

The ETM Department has the responsibility to ensure all aspects of the program including continuous improvement of the interdisciplinary curricula, co-operative work study assignments, capstone design projects and professional employment. 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 once the interdisciplinary program was promulgated there were several transfers from the EE and ME degree programs.

Only existing courses in EE and ME with their strict prerequisites are integrated into these academic concentrations for the BSE program. This implies no additional courses or faculty and assures compliance with the general criteria for accredited baccalaureate programs and utilization of existing assessment activities for the program educational objectives and student outcomes. However, the interdisciplinary Engineering program, also uniquely within the College, includes two requisite courses in engineering economics and human resource management.

This is a critical review of the genesis of the BSE EME and EPE curricula and the continuing academic and administrative path taken in its development in the nine years to date [1]. Presented here from this experience are the lessons learned and pitfalls to be avoided to obtain accreditation and academic concentrations for such an interdisciplinary BSE program from existing BSEE and BSME programs.

The Disciplines Are Too Disciplined

The EE discipline was once embellished with a significant number of ME courses suitable for between-the-world-wars technical training [2]. Even as late as the 1960s EE students were required to take ME courses in statics, dynamics, nature and properties of materials, and thermodynamics [3].

The rapid development of microelectronics, digital communication and control and the microprocessor in the 1970s shifted the extent of the EE curriculum away from these courses. The result is that most, if not all, EE curricula today do not feature any substantive courses in ME [4].

The ME discipline often requires a single course and laboratory in direct and alternating electrical circuits, electrical power and analog and digital electronics. Subsequent and limited elective courses in the ME discipline may include sensor integration and processing and electromechanical machinery. The result is again that most, if not all, ME curricula today do not feature any substantive courses in EE [4].

Development of an Interdisciplinary Program

The integration of courses from another engineering discipline into an undergraduate degree program may 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 a discipline degree program.

EE courses such as electromechanical systems and power generation and transmission require prerequisite EE courses in applied electromagnetics and electrical transmission lines. ME courses such as heat and mass transfer and renewable and alternative energy require prerequisite ME courses in dynamics, the mechanics of solids and fluids and thermodynamics. Thus, within the limited confines of the EE and ME discipline elective courses, there is no opportunity for effective interdisciplinary study in EME or EPE.

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

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 do provide a creditable engineering education but may not be able to offer a plethora of elective courses. In the latter case, the programs seem to be lost in the torrent of engineering discipline degree programs. On occasion and 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 engendered the necessary cooperation from the established EE and ME Departments of the

College. The BSE program shares the 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].

The choice of the names of the BSE EME and EPE academic concentrations were quite intentional. In the first instance, some institutions use *mechatronics* for either an interdisciplinary program or a somewhat limited minor, usually in ME. EME seems to connote a clearer reflection of the breath of the interdisciplinary curriculum between the EE and ME disciplines. While in the second instance, *energy* alone is likewise used again for either an interdisciplinary program or a somewhat limited minor, usually in ME. Power in the name EPE indicates the topics inherent in that part of the EE discipline for the interdisciplinary curriculum.

There are other names seemingly endemic for these interdisciplinary programs at other institutions, such as *robotics engineering* or *sustainable (or renewable) energy engineering*. However, these names were dismissed as contrary to the intent of the BSE EME and EPE program to be collegially forged from the BSEE and BSME programs [1], [7]. These names, often used by EE and ME departments for a minor, would not have promoted the requisite cooperation for the genesis of the BSE program.

The BSE EME and EPE academic concentrations were deemed not to be majors *per se* since they result in a degree without such a designation, unlike a major in EE or ME resulting in the BSEE or BSME degree. In addition to these academic concentrations, which appear as such on the transcript, the BSE degree program also provides less restrictive study plans in Computer Hardware and Software Engineering with computer science and Engineering Fundamentals across all departments of the College of Engineering.

Interdisciplinary Program Administration

The interdisciplinary BSE program was initially established in 2012 with a Director and administered in the College of Engineering but became a part of the newly created Department of Engineering, Technology, and Management (ETM) in 2019. Other degree programs within ETM include the BS Engineering Technology, the BS Industrial and Systems Engineering and the MS in Engineering Management. There are separate directors of each degree program and a departmental chair.

The Director has the responsibility to ensure that all aspects of the interdisciplinary BSE 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 Director and faculty advisors from both EE and ME provide support for appropriate course selection, seamless integration and continuing professional development. However, current the

undergraduate student enrollment in the BSE program remains lower (120) than that in the BSEE (320) and BSME (580) programs. But this is not any criteria for success because the BSE program requires no additional faculty or resources, yet it affords an opportunity for the focused student to pursuit an interdisciplinary professional career.

Interdisciplinary Curriculum

The curricula for the BSE EME and EPE programs feature a common freshman year with the BSEE and BSME programs focusing on the profession, preparatory skills and retention. 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. However 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 curricula of the BSE EME and EPE programs. All EE and ME 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.

An innovation for the College 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. The common freshman year curriculum for the BSE EME and EPE programs is as follows:

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
Intro to Engineering Problem Solving
Engineering Computation
Fundamentals Mechanical Design

Concentration in Electromechanical Engineering

The BSE academic concentration in Electromechanical Engineering (EME) emphasizes all aspects of applied 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.

The ME courses follow the thread of graphics, statics, dynamics, the mechanics of solids, dynamic systems and machine theory and design. The 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 engineering approved electives can be selected from such EE and ME courses in signal processing, embedded system design, kinematics and robotic control. The curriculum for the BSE EME program is as follows:

<p>Third Semester</p> <ul style="list-style-type: none"> Calculus III Elementary Classical Physics II Engineering Statics Electric Circuits GenEd Intellectual Heritage I 	<p>Fourth Semester</p> <ul style="list-style-type: none"> Differential Equations Engineering Dynamics Mechanics of Solids Electric Circuits Lab GenEd Intellectual Heritage II
<p>Fifth Semester</p> <ul style="list-style-type: none"> Digital Circuit Design and Lab Electromechanical Energy Systems and Lab Technical Communications Engineering Analysis and Computation GenEd Human Behavior 	<p>Sixth Semester</p> <ul style="list-style-type: none"> Processor Systems and Lab Engineering Seminar Probability and Statistics GenEd World Society GenEd Race and Diversity
<p>Seventh Semester</p> <ul style="list-style-type: none"> Senior Design Project I Machine Theory and Design Engineering Economic Analysis Engineering Approved Elective GenEd The Arts 	<p>Eighth Semester</p> <ul style="list-style-type: none"> Senior Design Project II Engineering Approved Elective Human Resource Management GenEd US Society Free Elective

Concentration in Energy and Power Engineering

The BSE academic concentration 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.

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

Three engineering electives provide the opportunity for further interdisciplinary study with the prerequisites in both EE and ME having been satisfied. The engineering approved electives can be selected from such EE and ME courses in digital logic, processor systems, power electronics, combustion or renewable energy. The curriculum for the BSE EPE program is as follows:

Third Semester	Fourth Semester
Calculus III	Differential Equations
Elementary Classical Physics II	Classical and Statistical Thermodynamics
Engineering Statics	Engineering Dynamics
Electric Circuits	Electric Circuits Lab
GenEd Intellectual Heritage I	GenEd Intellectual Heritage II
Fifth Semester	Sixth Semester
Electromechanical Energy Systems and Lab	Introduction to Electromagnetics
Mechanics of Fluids	Heat and Mass Transfer
Technical Communications	Engineering Seminar
Engineering Analysis and Computation	Probability and Statistics
GenEd Human Behavior	GenEd World Society
	GenEd Race and Diversity
Seventh Semester	Eighth Semester
Senior Design Project I	Senior Design Project II
Engineering Economic Analysis	Human Resource Management
Power Systems Analysis	Engineering Approved Elective
Engineering Approved Elective	Engineering Approved Elective
GenEd The Arts	Free Elective
GenEd US Society	

Pitfalls to be Avoided and Successes to be Had

The basic concept of interdisciplinary engineering study, especially between the naturally related subdisciplines of EE and ME in EME and EPE, is not unique [8]. However, nurturing such an interdisciplinary BSE program can be somewhat problematic and susceptible to certain pitfalls unless possibly implemented as suggested here.

One avoided pitfall was that there is no inevitable conflict for resources since only existing courses and faculty from EE and ME are utilized. The BSE program Director consults regularly on academic concerns with the BSEE and BSME program Directors, who in this instance are also chairs of their discipline departments. With this organization the BSE program Director is in a sense an intermediary and can focus on pedagogical and not necessarily departmental concerns.

Promotion of the interdisciplinary BSE program to the constituents of the program, both students and employers, must also be evident from the faculty advisers of the EE and ME discipline programs and the College advising staff. This is only reasonable since they certainly desire that students be well prepared to face the engineering challenges of the 21st century. An interdisciplinary BSE program between EE and ME then is another reasonable manner by which that can be accomplished. The BSE program becomes the scheme by which the EE and ME disciplines can each benefit from additional course enrollments and students have a greater scope of professional career choices [8].

The promotion of the BSE EME and EPE program is now significantly enhanced with the establishment of academic concentrations in 2020. At its inception the BSE program utilized study plans with general and specific course outlines in several areas. However, the EME and EPE academic concentrations signify a specific accomplishment and appear on the transcript and diploma.

Interdisciplinary degree programs with a variety of models of execution have been studied in research in engineering education [9], [10], [11]. The perceptions of students in an interdisciplinary engineering curriculum are significant to the overall success of the degree program [10]. These students may initially perceive that they are not quite equal to their EE and ME discipline colleagues.

However, these perceptions were allayed when the BSE EME and EPE students compared the breadth of their training to those in the EE and ME disciplines with a limited minor in these areas. The results of surveys and interviews have confirmed this premise [8]. The EE and ME discipline students can at best, but usually with difficulty because of the prerequisites, obtain the same measure of interdisciplinary training.

Another possible pitfall is appropriate laboratory and projects within an existing EE or ME course, originally designed for those discipline students, may be an issue for the interdisciplinary BSE student. This may also be a concern for the program educational objections and an aspect of ABET accreditation.

However, the paradigm here is that the BSE student, because of the extensive discipline course prerequisites, is essentially either an EE or an ME for the courses within the focused threads of EME and EPE. Thus, the attainment of course learning objectives and program outcomes are aligned by intent and not disparate. There is no conceptual difference in performance to be expected and as such aggregate metrics can be used in the assessment.

Finally, a demonstrable success though is in the capstone senior design sequence. Teams composed of EE, ME or EE and ME students have been indirectly assessed to have augmented performance by the inclusion of BSE EME or EPE students on projects in electromechanics or energy and power [10].

The existence of an interdisciplinary BSE program can 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 [10]. 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.

Professional Careers and Graduate Education

Of course, the BSE EME or EPE 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 BSE EME and EPE programs could certainly include additional graduate courses in EE and ME since they have had the undergraduate 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.

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 EME and EPE 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 EME and EPE program and its curriculum.

Are you satisfied with the courses taken in 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 BSE EME and EPE academic concentrations. Employers as constituents also are keen to embrace this new paradigm and recognized, for their specific concerns, a profound shift in undergraduate engineering education.

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. The interdisciplinary BSE program utilizes course evaluations, surveys and program outcome alignment from the BSEE and BSME programs.

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