[Work-in-Progress] Broadening Engineering Formation: Lessons Learned from Multidisciplinary Engineering (MDE) Degree at The University of Connecticut

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BROADENING ENGINEERING FORMATION: LESSONS LEARNED FROM MULTIDISCIPLINARY ENGINEERING (MDE) DEGREE AT THE UNIVERSITY OF CONNECTICUT

Abstract

Engineering and technological improvements have been deemed essential to solving some of the most pressing contemporary issues in society and our environment. Newer generations of engineers are now required to bring not only technical skills and knowledge but also the capacity to work in multidisciplinary teams and make decisions using system-based perspectives (NAE, 2005). The variety of scenarios and complex systems have traditionally been addressed by different specializations in engineering and other related disciplines; however, rapidly changing, and emerging fields in engineering require a dynamic educational environment that can ensure the workforce in the near future can respond to the challenges posed by diverse, complex new societal challenges. In that view, multidisciplinary engineering degrees offer a more rigorous, flexible, and mission-driven vehicle for developing this workforce than conventional engineering instruction. This paper describes a multidisciplinary degree program in the School of Engineering at the University of Connecticut and key lessons from its creation.

Introduction

This paper explores the experience of creating a new multidisciplinary engineering (MDE) major and its specializations contained within the University of Connecticut, a R1 level University in the Northeastern United States. We describe what we learned in the process, including the challenges we faced in the initial launching and implementation of its core curriculum and its different tracks. We then discuss lessons learned that can inform the development of a more diverse and open field of engineering.

Beginning in the mid-2000s, the School of Engineering (SoE) began to receive feedback from multiple stakeholders – including prospective students, parents, enrolled students, national agencies, and employers – during open house events and other gatherings, all of whom voiced the need for a curriculum that would fit a broader range of interests and would respond to new and complex challenges in society. Related trends are captured in recent reporting by the National Academy of Sciences [1], including the shift in national and global economic direction, changes in consumer habits, concerns about sustainability, accelerated product life cycles, and new trends in nationwide industrial developments. Additionally, engineering students are expected to possess a wider range of skills and communicate across a variety of disciplines, which might include product design and development, installation, testing, operation, and maintenance [2].

All of these signs reflect a growing awareness of the need for an educational model that will respond to rapidly evolving challenges. The National Academy of Sciences has raised the concern that the current educational model should better align existing engineering models with such emerging challenges, broadening the context through an increased number of thematic calls and engaging with a wider range of users. In addition, academic literature on Science, Technology, and Society has called for a move towards a heightened awareness of the context and factors that influence engineering decision-making by opening engineering formation [3].

Our School of Engineering seized the opportunity to be a part of this pedagogical shift and worked to create a new MDE major under its name, with four unique specializations: entertainment engineering; human rights and sustainability; industrial design; and an individualized specialization that offers a framework to help realize a student's unique set of interests. Our administrators were aware that the success of the program would hinge on working with established departments, institutes, and areas of study across the university. In many instances, classes would not need to be created from the ground up but rather could be cross-listed and/or taught in teams. The new degree would also need to follow ABET's requirements for accreditation, which entail a readiness review, a request for evaluation, a self-study, and an on-site visit at the conclusion of the process.

Our aim in this paper is to explore lessons learned that serve as a focal point for discussion of similar initiatives – which together aim at broadening engineering education and building a workforce with a collaborative and interdisciplinary mindset.

Program Description

Our University's MDE is grounded in a core of engineering courses drawn from across the school, plus a student's chosen "specialization" (i.e., a 24-credit roadmap for students to combine their engineering coursework with partner programs, leading to unique fields of study). At present, there are three key specializations in the MDE major.

First, Entertainment Engineering aims to provide engineering students with a solid background that integrates engineering and performing arts. The second area, Industrial Design, aims to provide students with the necessary skills to solve complex engineering problems as they relate to creating products, services, or systems in the larger context of human experience (such skills are honed through the study of human factors and ergonomics, through brainstorming sessions aimed at developing unique forms of product innovation, through the creation of drawings or prototypes or computer models, and/or through processes aimed at identifying and addressing true user needs). The third area, Human Rights and Sustainability, focuses on providing students with a core skill set to understand, assess, and manage engineering's social and environmental impacts. In this area, engineering students are embedded in courses with students from multiple fields (e.g., humanities, social sciences, and arts) who together focus on a range of industries and

functions, from product design and life-cycle analysis to supply chain management to innovation in sectors such as renewable energy.

As developed, our MDE major serves two main goals at the University of Connecticut. The first is to provide students with concrete skills and professional exposure to engineering-related fields, such that they can develop and bring unique knowledge to bear on complex problems at the intersection of engineering and other fields. The second goal is to provide a robust platform (through the specialization structure) from which the school can respond to societal demands, student interests, and industrial needs in a timely, integrated, and agile manner.

Our MDE degree creates a strong foundation of classes that cover 34 credits in math and science and that share a common approach with many other engineering disciplines across the university: General Chemistry 1 and 2, Calculus 1 and 2, Physics 1 and 2, as well as Multivariable Calculus, Differential Equations and Statistical Methods, with a load that varies from 3 to 4 credits per class. Additionally, the MDE program covers other Engineering classes for a total of 47 credits, such as Electrical Circuits, Fluid Mechanics (+lab portion), or a collection of Engineering Electives, in line with ABET's recommendation of covering topics such as basic science, college-level mathematics, and engineering design.

The first-year curriculum is common across most majors in the School of Engineering. Students are encouraged to use the first-year engineering coursework (ENGR 1000; CSE 1000) to expand their knowledge of the engineering paths available to them at the University and the broader paths of engineering as a field. Students interested in Multidisciplinary Engineering will begin to engage in an area specialization coursework in their second semester and will continue to hone their focus throughout a plan of study. In tandem with the general engineering curriculum, students work closely with their academic advisor to list specialization-specific coursework in their plan of study that closely aligns with their career goals.

In addition to courses in the School of Engineering and associated programs, the MDE major offers a two-semester capstone project in all four areas. The capstone course encourages students to work on a single topic of investigation. The MDE program culminates in a presentation of team-based projects in the senior year. Those projects typically have industry sponsors.

Program Development

Historically, students entered our School of Engineering through a direct-admit model, declaring their major at the time of matriculation. The school had a path for those students who did not declare a major, called *Undecided Engineering*. This nomenclature reflected several weaknesses, including a lack of a terminal degree, minimal community, and negative connotations associated with the word "undecided."

By contrast, the MDE major provides a structured path through which students pursue a generalized engineering curriculum and can select from four new specializations (including the individualized approach for those who would still want to carve a unique path), all with the careful guidance of an Advisor. The MDE directly addresses several of the weaknesses of the previous Undecided Engineering model: it provides a terminal degree that students can pursue from their first year through graduation; it provides a renewed sense of community through a named major; and it replaces the word "undecided" with the more positive term "multidisciplinary," which reflects the breadth and excitement of the field.

At the onset, the school administration worked to create the MDE framework and the core curriculum, with the approval of the school's Committee on Curricula and Courses and various university offices. An advisory committee with representatives from all departments contributing courses to the MDE major was formed and analyzed other MDE programs throughout the US as potential models. Additionally, the committee identified partnered faculty in each specialization across disciplines. The deans of multiple schools and colleges within the single university worked on establishing relationships across a wide variety of external departments, schools, and institutes, each with distinct disciplinary backgrounds. In the case of the Human Rights and Sustainability specialization, the collaboration was extended to thirteen cross-listed courses in total.

Administration and Advising.

The Dean and Assistant Deans who helped create these specializations monitor the advances of these four areas of study and have given the faculty involved the chance to present their unique offerings under a new MDE banner that is introduced twice in the Fall semester during Open House events. These open sessions with the public, faculty, administrators, and advisors have been welcomed by students and their families, who arrive at our university seeking knowledge and academic opportunities for developing their unique interests. Our School of Engineering recognizes that there may yet be additional new opportunities, such as music and engineering. While it is too soon to determine whether this could constitute a fifth specialization, our existing Individualized Specialization offers the mechanism to bridge these fields without having to create a new specialization.

Innovations in Teaching Formats.

The Center for Teaching and Learning at our university funded six faculty members to attend a Summer 2022 program hosted by Worcester Polytechnic Institute's Center for Project Based Learning (PBL), which involved the departments of Mechanical Engineering, Biomedical Engineering, Material Science and Engineering, Civil and Environmental Engineering, and the Department of Art and Art History. This experience helped deepen collaboration across Mechanical Engineering, Biomedical Engineering, and Chemical Engineering in the writing of grants and pursuing combined projects on case-based learning scenarios.

Enrollment

The School of Engineering, under the umbrella of the Multidisciplinary Engineering degree, enrolled a total of 31 students for the year of 2022-23, and 32 for the year 2023-24, combining all four specializations: Entertainment Engineering, Human Rights and Sustainability, Individualized Specialization, and Industrial Design. Additionally, there are two students admitted for June 23 in Industrial Design and one in Human Rights and Sustainability. While the school is not considering the addition of new specializations, it is always ready to hear from other emergent areas of study, inside and outside, which could fit in the larger framework of an Individualized Specialization. This flexibility to build new programs is a distinct strength, particularly if there are students who are interested in being engineers but do not want to fit in a standard program of studies, like Mechanical Engineering or Electrical Engineering. This method allows our school to respond in an agile way, with an offering of 24 credits that can be used towards new specializations or tracks. This selection can be augmented with the choice of other electives and the choice of an appropriate capstone project that can deepen the study of new and emerging areas of interdisciplinary work.

Areas of Specialization

Entertainment Engineering Specialization.

The Entertainment Engineering Specialization originated through a series of pilot courses offered by the SOE jointly with the School of Dramatic Arts. Undergraduate Engineering students joined Drama students in coursework that explored the engineering curriculum, which was then applied to the entertainment industry. The specialization was modeled in part on the Division of Interdisciplinary Engineering Studies at Purdue University, which had previously created a program in undergraduate engineering instruction [4], following ABET accreditation directions. Since its founding in 2004-2005, Purdue's program created a unique educational pathway for engineers in many fields, such as acoustical engineering, educational engineering, engineering management, or theatre engineering, among others. Our Entertainment Engineering specialization has built on this model, recognizing that in this field, engineers often must obtain knowledge across fields spanning aspects of civil engineering, mechanical engineering, electrical engineering, and computer engineering while at the same time drawing insights from classes such as Asian Theatre and Performance, Women in Theatre, Scene Construction or Rigging.

Our MDE major has benefitted from the simultaneous creation of a new institute, the Krenicki Arts and Engineering Institute, created as a joint effort between the Arts and Engineering. With a major ($5 million) philanthropic gift, our donors set the goal of establishing an innovative center that would deepen connections between Engineering and Fine Arts. The resulting specializations in Entertainment Engineering and in Industrial Design have deepened our core curriculum, and the center is now funding research projects, seminars, lectures, and the purchase of materials intended to benefit students in these two areas.

Human Rights and Sustainability.

Perhaps more than any other profession, engineering has the potential for extensive and enduring impact on human and environmental systems. For centuries, technological developments, ranging from aqueducts and interstate highway systems to the advent of electronic computing, have been catalysts for significant changes at multiple levels of society. This specialization works on forming a curriculum that transmits knowledge of public well-being and ethics to our undergraduate engineers while exploring a wide range of issues that affect public welfare, including social exclusion, poverty, and hunger [5].

A key question that students in the MDE program are often asked to reflect on is "*What is the role of engineering in society*?" Building upon earlier touchstones -- from the revolt of engineers in the 1920s (Layton, 1986) to Socially Responsible Engineering in the 2020s (Smith & Lucena, 2020) - progressive engineers have invoked a greater purpose of engineering for society. They have built new areas of practice, such as humanitarian engineering, and have laid out shared professional goals such as the Grand Challenges for Engineering adopted in the adopted in the early 2000s by the National Academy of Engineering. Yet all these efforts lack a universal baseline and objectives (i.e., a standard and goals that apply to all peoples) to guide the work of engineers towards that greater purpose.

Therefore, in this specialization, we show how a human rights and sustainability-based framework can provide an encompassing language to advance these goals, grounded in foundational concepts such as human dignity and the principles of universality, indivisibility, and equity. We offer courses in five separate segments: core courses; history, philosophy, and theory; applications and methods; elective courses; and capstone courses. The wide variety of classes integral to this highly interdisciplinary specialization are cross-listed with different departments, institutes, and programs: the Africana Studies Institute; Anthropology; Asian and Asian American Studies Institute; Department of Curriculum and Instruction; Department of Economics; Department of Geography; the Gladstein Family Human Rights Institute; Department of History; Department of Natural Resources; Department of Political Science; School of Business; Department of Sociology; and Women's, Gender, and Sexuality Studies.

Industrial Design.

Industrial design has been traditionally taught as a Bachelor of Arts (B.A.) or Bachelor of Fine Arts (B.F.A.) in the United States; other programs have offered it as a Bachelor of Science (B.S.). While the former focuses more on humanities courses in a broader range, the latter concentrates more on the technical aspects. The approach by the SoE to offer this undergraduate industrial design specialization breaks that tradition, but at the same time, honors the fact that most practicing industrial designers work seamlessly and extensively with engineers from many disciplines, and that makes them often de-facto engineers, but without the certification and technical knowledge to perform advanced calculations.

In some circumstances, practicing industrial designers have felt the need to pursue a technical degree to obtain the necessary skills and knowledge. Yet often, engineering professionals are the ones who eventually must complete a Master's Degree in Industrial Design in order to fill gaps in knowledge. That is the case, for instance, with the recently formed Design Engineering Master's program offered by Brown University in partnership with the Rhode Island School of Design (RISD). That program aims to give a studio-based educational format to students coming from a wide range of backgrounds, including engineering studies.

The coursework offered in this specialization is mostly studio classes, where in many instances, the assignments and workload are completed with the direction of an external client or by advancing a research project that the student carries out through a different department on campus. Additionally, many of the offerings are cross-listed with the Art and Art History Department, which allows MDE students to become familiar with a new experiential learning scenario.

This specialization was a new creation at our university and posed a unique set of challenges, ranging from writing and preparing core and elective courses to creating the right educational sequence. A second challenge that professors and administrators faced was that this study area shares many points of contact with disciplines like mechanical engineering, materials science, or management and engineering for manufacturing; however, few schools combine it in a single offering.

Individualized Specialization.

This unique offering responds to the interest of students who want an engineering education at the core but also want to pursue a unique professional direction. This path allows students to forge interdisciplinary partnerships with other campus stakeholders to promote their development as future professionals. Students may use the individualized specialization as a pathway to further education in medicine, law, engineering education, business, or other fields. Students work closely with their academic advisor and the MDE faculty review board to design learning outcomes and objectives related to the pursuit of their tailored specialization coursework, outline a plan of study and appropriate course sequencing, and monitor degree progress.

Lessons Learned

Discussions and work to form the MDE program at the University of Connecticut started in 2019; four important lessons have emerged since then. Insights from this experience could be helpful to other colleges and universities interested in creating similar programs. Our synthesis below draws as well on experiences from similar programs, such as the MDE program and Purdue University. Our principal lessons follow:

Lesson 1: Build upon your current course offerings.

R1 universities such as the University of Connecticut have a significant pool of existing courses spread across 7 distinct engineering departments. Many of these courses are interdisciplinary in nature and can easily fit into the schemes of a multidisciplinary major. For example, a course on Brownfield Redevelopment in Civil Engineering covers not only the technical aspects of remediating contaminated sites but also legal, environmental, financial, and social aspects. Classes such as Assessment for Human Rights and Sustainability are co-taught by Engineering and Political Science faculty, providing a unique experience for multiple disciplines, including those enrolled in the MDE track on Human Rights and Sustainability. Our effort at scaffolding new courses atop the existing curriculum has enabled us to create a full suite of course offerings without having to start from scratch. Only a few wholly new classes were created, such as Engineering for Human Rights or Entrepreneurship and Innovation in Industrial Design.

Lesson 2: Consider the strengths and uniqueness of your program when designing sub-specializations.

Given the myriad of possibilities in a multidisciplinary engineering program, it was essential to draw upon academic programs within our institution that already benefited from an excellent national and international reputation in order to create the unique combinations central to our MDE program. For example, the Human Rights Institute is globally recognized as a center for research, teaching, and policy engagement in the field of human rights. Similarly, the School of Fine Arts is well known for its experiential learning approach to education which combines four academic departments: Art and Art History, Digital Media and Design, Dramatic Arts, and Music.

These two programs are highly interdisciplinary, facilitating integration with the School of Engineering. Furthermore, existing efforts such as the Engineering for Human Rights Initiative and the Krenicki Arts and Engineering Institute at our institution were used as a platform for new curriculum development. The Human Rights Institute and the School of Fine Arts are at the core of the Human Rights and Sustainability and Entertainment Engineering specializations within the MDE. This approach not only creates new synergies with those existing programs but also supports the flexibility of the program as it evolves; our aim is to attract larger numbers of students to those specializations progressively. This high level of interdisciplinarity also means that other universities/colleges creating MDE programs can draw upon their own unique mix of disciplinary strengths to create the specializations offered at their respective institutions.

*Lesson 3: Create strategies to address departmental/program differences***.**

Working across different disciplines can be challenging. Although the MDE program fosters an environment for synergies among departments within the university, it also exposes some differences in terms of goals, priorities, and learning approaches for students across all programs involved. Therefore, work plans should allocate a significant amount of time for dialogue and

coordination among faculty, advisors, and administrators concerning the nature of goals, tradeoffs in competing interests, and the scope of program activities. All stakeholders need to be aware that patience and communication are crucial, and they need to be intentional about interdisciplinarity. Our experience required being intentional about our approach and also being willing to compromise in some areas. We used our funds judiciously, working toward creating specializations within the MDE program that would reflect the comparative strengths of the university.

Lesson 4: Consider ABET accreditation from the beginning.

ABET accreditation is a key component in any engineering program, and the design of the curriculum of each specialization and sequencing of classes within the MDE program should be focused on fulfilling and reinforcing any given School of Engineering's commitment to ABET's overall educational objectives. Our program was built with ABET accreditation in mind from the early planning stages. We ensured that our core degree choices would meet the requirements for this accrediting body, and our assessment plan was integral to our overall planning from day one of the curricular programs. It was not an afterthought.

Concluding Remarks

A reflection of the lessons learned from the MDE program at the University of Connecticut shows that it was important to learn from the experiences and successes of other programs, such as the one at Purdue University. Similarly, the School of Engineering took advantage of the existing coursework to create a strong framework of core curriculum classes, which are the key components of the MDE program. Therefore, the MDE became a flexible platform to build in-demand specializations with partnering departments making capital of their unique strengths and program offerings. Being an R1 institution with an established Human Rights Institute and a Fine Arts school with many disciplines, the deans from these schools worked to secure external funding from donors to establish two of its specializations in Industrial Design and Entertainment Engineering. Equally, they worked with the Human Rights Institute to secure a broad selection of classes that would fit another specialization.

Similarly, all stakeholders have to work together patiently, and the work plan should allocate resources to facilitate discussions of goals and competing priorities and establish a common vision. This process was facilitated by institutional support and funding (e.g., a private donation to establish a partnership between the School of Fine Arts (SFA) and the School of Engineering). On a granular level, communication across schools proved to be challenging at times, such as in diverging learning approaches on occasion, as well as separate goals and competing interests, but patience and communication were key. Deans and directors were intentional in the creation of curricular plans that followed ABET accreditation and that outcomes would be assessed property.

The engineering world continues to evolve, and engineering schools need to address the silo effect of offering specialized areas without regard for collaboration and multidisciplinary efforts [6]. More students need to matriculate through programs grounded in multidisciplinary approaches to engineering, especially at the undergraduate level. In time, we anticipate that such approaches will become normalized throughout the field. Schools that continue to offer conventional engineering education without carefully analyzing these trends will dilute resources and miss the opportunities to develop talent in fields with solid professional potential.

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