The Challenges of Implementing an Engineering Program at a Small Liberal Arts College

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Abstract

The prospect of introducing an engineering major on the campus of a small, private liberal arts college gives rise to a set of difficulties that may not be faced at larger, public universities. This paper will trace the development of such a program from inception to implementation up to the year before the program goes online. The impetus for proposing such a program will be outlined as well as the steps that were taken to craft a proposal that would fit into the context of a small liberal arts college. The process of navigating administrative and faculty approval will be analyzed and recommendations will be given for faculty seeking to introduce similar programs. The initial work of establishing the assessment infrastructure that will lead to eventual ABET accreditation will also be presented.

The Impetus for Engineering Science at Muskingum College

Muskingum College is a small liberal arts college in southeast Ohio. Undergraduate enrollment is approximately 1700 with an additional 1400 students taking graduate classes. The academic majors span the traditional disciplines in liberal arts and sciences found at most private institutions of comparable size. For many years the physics department has been comprised of two regular faculty members teaching a service component and a small number of majors. There has also been an option to begin their studies at Muskingum and transfer to another institution to complete an engineering degree, sometimes also receiving a degree from Muskingum.

The decision to propose an Engineering Science major within the Physics Department at Muskingum College had two primary motivations. The first was a history of fluctuating – but generally low – enrollments in the physics major. It was felt that the department may be in danger of losing the major and facing a service-only existence in the event of campus-wide financial or enrollment difficulties. An accredited general engineering program that shares a common core with a modified physics major was proposed to increase enrollments. The department was renamed to Physics & Engineering and the new general engineering major was tailored to attract and prepare students for careers in industrial research & development or graduate school. The program will be particularly appealing to students who are interested in engineering but who would prefer to attend a small college.
The second motivation was related to a projected downturn in college enrollments after 2009 in Ohio. This was reported by the Western Interstate Commission for Higher Education (WICHE) in 2004\textsuperscript{1}. Decreased enrollments are predicted to persist until 2015 and prospective college students will be comprised of higher percentages of minority groups for which college attendance is lower than the norm. The introduction of new programs is one of Muskingum College's primary strategies to maintain current enrollment levels after 2009. Surveys consistently rate engineering high on the list of majors in demand by entering college students. In addition, Muskingum College has observed consistent interest from prospective students in studying engineering for many years.

Crafting the Proposal

The crafting of a successful engineering proposal at Muskingum College involved accommodating several constraints and considerations. Some of these constraints originate with the Accreditation Board for Engineering and Technology (ABET) and apply to all general engineering programs. A second set of constraints arises when considering student preparation for the Fundamentals of Engineering (FE) exam. Finally, the small size of our college/department and the nature of the institution itself introduces another set of considerations. What follows is an explanation of the way the proposal was adapted to fit each set of constraints.

Constraints Imposed by ABET

The constraints and requirements relevant to accreditation of a general engineering program are published by ABET\textsuperscript{2}. These include – but are not limited to – Program Educational Objectives, Program Outcomes and Assessment, and a Professional Component that stipulates particular elements in the curriculum. An analysis of these criteria was key to designing a curriculum that would meet or exceed ABET program expectations.

The Professional Component of the ABET Criteria requires 32 credit hours of mathematics and basic sciences. Our proposal required 33 hours including: the classical physics sequence, 3 semesters of calculus, linear algebra, differential equations and the general chemistry sequence. This component also requires 48 semester hours of engineering topics. Our proposal required 49 hours including within the department: an introductory engineering course, Statics & Dynamics, Optics, Thermodynamics, Electromagnetics, Material Science, Principles of Design, Measurements, Fluid Mechanics and a senior design project spanning two semesters. In addition, microeconomics and a moral inquiry ethics elective were required.

In addition to the above requirements related to credit hours, the ABET criteria clearly identifies key outcomes that must be demonstrated by students. These outcomes had to be addressed during the process of constructing the curriculum. It was felt that the most effective way to incorporate many of these essential outcomes was to thread them throughout the curriculum from start to finish. These threads comprise major themes in the philosophy of the program and will manifest as a continuous accumulation of skills and knowledge. The following threads were identified:
Experimental: setting up, executing, analyzing, and refining traditional and computer-based experiments.

Computational: use and implementation of computational methods to solve and visualize specific classes of problems with MATLAB and LabVIEW

Multidisciplinary Design: experience executing the stages of the design process culminating in a team-driven capstone design project with participation by faculty from multiple disciplines

These threads will be woven throughout the curriculum with the deliberate goal of increasing student proficiency in each area as they move toward the capstone experience.

It should also be mentioned that another thread was included in the curricular plan for the purpose of giving the program a distinctive character. Being a general engineering program, our curriculum will adequately prepare students to enter the workplace and move toward professional licensure or to continue their studies at the graduate level. It was decided to also tailor the program to specifically equip students with the skills to excel in an industrial research and development environment. Many of today’s emerging technologies involve engineering as it is applied to cutting edge research in physics (e.g., photonics, microelectromechanical and nanoelectromechanical systems). To this end, it was decided to thread a material science component through the curriculum as well. Students not only will be required to take a formal course in material science but also will be exposed to fabrication, characterization and the theory of materials throughout the entire curriculum.

Constraints Imposed by NCEES

A second constraint involves the requirements for professional licensure by the NCEES. The first steps in this process are graduation from an ABET accredited program and successful completion of the FE exam. Preparation for the FE exam is not only one of the goals of the program but also is intended to be one of our assessment mechanisms. Therefore, an analysis of the FE exam informed the choice of topics in the curriculum to some extent. Below is a graph that shows the subjects included in the FE exam and their relative weights as reported by the NCEES.
What follows is a chart that shows how the proposed engineering science curriculum addresses the subjects comprising the FE exam. The designation 'P' in the chart refers to a course for which the subject matter in question is a primary component of the relevant course. A designation of 'S' indicates a topic that is of secondary importance for that particular course.

Institutional Considerations and Constraints

No program is developed in vacuum and our proposal had to reflect the realities of the environment within which we work. Muskingum is a small liberal arts institution with academic standards and policies that present a framework into which any new program must fit. The small size of the department not only partially explains the impetus for proposing a new major but also necessarily limits the resources available for its implementation. It is also true that the size of the college itself presents resource limitations.

“Proceedings of the Spring 2007 American Society for Engineering Education North Central Section Conference at West Virginia Institute of Technology (WVUTech), March 30-31 2007”
The introduction of an engineering program at our particular institution made the total credit hour requirements of the program an important consideration. Currently, academic policy restricts the total number of credit hours to 40 that can be required for a major from any single discipline. This would have frustrated any effort to craft a curriculum that satisfied ABET criteria by requiring too many hours from a conjoined physics and engineering department (i.e., discipline). We were able to petition for an exemption based on the importance of fulfilling the requirements for ABET accreditation to the success of the program and on the precedent for exemption already set by other externally accredited programs on campus.

Any realistic plan to implement such a program had to take into account the limited resources available to the physics department at the time of inception. This included: a limited number of faculty to teach courses for the existing physics major and the new engineering science major, to advise students academically and professionally, and to oversee student projects; limited space within the department; and limited library resources.

Given the considerable overlap in subject matter between physics and general engineering, the physics curriculum was modified and the engineering science curriculum was designed so that they share a common core curriculum. In addition, existing faculty and staff with engineering credentials were contacted to identify opportunities to involve them with the development, implementation and assessment of the program.

With the impending introduction of not only engineering science but also other new programs as well, space requirements have become a pressing issue. Our engineering proposal calls for two new faculty members in the next two years and a dramatic increase in the number of majors within our department. Space had to be found to house the new faculty and to accommodate many more students. Fortunately, the existing physics department possesses a considerable amount of space. Plans were made to better utilize existing storage areas to accommodate the introduction of new lab components associated with the courses in Statics & Dynamics, Optics, Thermodynamics, Electromagnetics, Material Science, Measurements, and Fluid Mechanics. Since space is now at a premium, we also decided to propose modifications to two existing spaces previously used only for laboratory sections so that they can serve double-duty as lecture classrooms. It was felt that reorganizing and better utilizing existing space and limiting the request for new space to faculty offices would make the proposal more palatable.

Library resources are also a concern, especially from the perspective of the satisfying ABET accreditation criteria. Muskingum's library collection at 215,000 volumes is relatively small and contains very little of direct relevance to an engineering program. With the help of library staff, we were able to determine the approximate cost of supplementing library materials at a level that would adequately support our new program. To cover the cost, we reassessed our spending priorities within the startup fund provided by the administration so as to allocate sufficient resources to provide for this important component.

Navigating the Approval Process
The approval process is a function of the policies and procedures of the particular institution. An awareness of this process and the relevant constituencies affected by the proposal are vital to its construction and to navigating the process. At Muskingum the necessary steps were: submission and approval of concept by administration, approval of concept by faculty, submission and approval of curriculum by Curriculum Committee, and approval of curriculum by faculty. The program has to be modified to fit the institution and this often involves compromise. At each step potential difficulties can arise that must be successfully dealt with. What follows is a retrospective on the process at Muskingum with recommendations to those engaging in a similar process elsewhere.

Submission and Approval of Concept by the Administration

It is necessary to first demonstrate the need for a new program to the administration. At Muskingum, the rationale for a new major was initially based on the low enrollments in the existing physics program. Our situation was no doubt made easier by the receptiveness of the administration to new programs given the demographic downturn on the horizon. The statistical data ranking engineering high on the list of majors desired by new students also helped to sell the idea to the administration. Finally, since the presence of engineering programs is typically confined to larger institutions they represent a viable niche market for smaller schools. In any case, a strong argument must be made that the program will increase the pool of potential students, complement existing programs and achieve a self-sustaining status within a reasonable time.

Several activities supported acceptance of the concept of an engineering science major. We worked closely with the Registrar and Admissions to collect hard data regarding student interest. Faculty and staff with engineering backgrounds were consulted at every stage of the process and invited to contribute to the program not only in the planning stages but also during future implementation. The multidisciplinary aspect was continually emphasized and faculty from other disciplines were encouraged to participate in future student projects. A consultant with expertise in a similar program was hired and tasked with assessing the feasibility of introducing a successful engineering science major at Muskingum.

Any new program necessarily requires an investment of resources. Part of our proposal laid out a detailed budget and tabulation of needed resources for implementing the program. This included salaries for new faculty, the cost of updating and acquiring new laboratory and demonstration equipment, computer hardware support and software needs, space usage and needs assessment, and an increased department budget to support design projects. In our case, there was no difficulty getting approval for the startup budget from the administration.

Approval of Concept by the Faculty

Once the concept was approved by the administration, it had to be approved by the faculty. The proposal form was distributed to divisions for discussion and then came up for a vote during a faculty meeting. There was immediate resistance to the concept due to the cost of implementation. It was felt by some that alternative programs represented a more cost effective means of increasing enrollments, and there were concerns that the funding necessary to
implement engineering science would emerge as shortfalls in budgetary support for existing programs. It became necessary for the administration to address these issues before the faculty. It was explained that all new programs were being considered on the basis of merit by the board and that separate funding had been set aside for implementation. When the vote was taken, the concept was approved by secret ballot by approximately 60%.

Submission and Approval of the Curriculum by the Curriculum Committee

The next step was approval of the curricular plan by the curriculum committee. This process was greatly facilitated by the quality of the proposal. Every curricular change was presented in detail including the impact on staffing and teaching loads. A plan to introduce the curricula for engineering science and the modified physics major was presented to demonstrate the feasibility of implementation and the adequacy of staffing resources. At the time the proposal was considered, the only remaining difficulty was the 40-hour limitation. The strength of previous concept approval by the faculty and precedent set by other accredited programs was sufficient to gain approval at this stage.

Approval of the Curriculum by Faculty

At this stage, the faculty had already approved the program in concept. With the recommendation of the Curriculum Committee, the program curriculum was approved with little discussion.

Recommendations Based on Our Experience

Based on our experience, we would give the following recommendations.

1. Communication with faculty – At Muskingum, the exact procedure for proposing new programs is ill-defined. Early on in the approval process we became aware that some faculty took issue with the initial approval of the engineering science program by the administration. It was felt by some that the faculty should not have been left out of this part of the process. Our recommendation is to first ascertain the exact procedure at the institution. If it is ill-defined or does not specifically include consultation with the faculty before administration approval, we would still recommend consulting with relevant faculty or faculty groups. This would make the intention to submit such an approval widely known and engender a sense of ownership for the concept outside the originating department or division.

2. Role of faculty – Once the proposal was formally presented to the faculty divisions, some pretty strident objections were raised concerning the level of funding and the funding mechanism. It was our understanding that the faculty's task was to assess the merit of the concept and not funding issues. In our case, the administration was able to alleviate such concerns and redirect the faculty's focus to the merits of the program. We recommend
clarifying these issues concerning the faculty's role at each stage of the process. We also recommend making every effort to keep funding issues separate from the consideration of the program itself on the basis of merit.

3. Faculty secretary – At Muskingum, the faculty secretary serves as a liaison between administration and faculty. As noted in the previous item, some difficulties arise that can be alleviated with clear communication between the administration and the faculty. Unfortunately, the reality is often quite different. We recommend utilizing the faculty secretary (or similar individual) to facilitate communication between faculty and administration. It seemed especially helpful in our case for many faculty members to hear the explanation of the administration's rationale for accepting and intended means of supporting the engineering science program from a respected member of the faculty itself.

4. External Consultation – Early on in the approval process, we solicited the use of an outside consultant to assess the feasibility of the new program. We feel the endorsement of a disinterested third party with a recognized level of expertise was vitally important to gathering support, especially in light of the aforementioned difficulties we were dealing with at this early stage.

5. Alumni Support – We were never privy to alumni feedback directly but our perception is that it contributed to the overall sense by the administration that our program was feasible and stood a good chance of success. We would recommend directing or requesting an effort to contact alumni that have gone on to careers in engineering or engineering-related fields. Positive feedback from alumni can oftentimes engender positive feelings among faculty that have mentored them or who value the perspective of former students.

Preparing for Accreditation

Once the proposal was approved, we immediately began putting together the assessment framework we would need for ABET accreditation. As mentioned, part of the preparation for accreditation arose when the curriculum for the program was being constructed. When the program was cleared to move forward, work began on the Program Educational Objectives and Program Outcomes mandated by ABET.

Program Educational Objectives

In ABET's "Criteria for Accrediting Engineering Programs", Criterion 2 requires programs to have published Program Educational Objectives (PEOs) consistent with the institution's mission and the other ABET criteria. Carter et al. have outlined a procedure useful for framing the program educational objectives across several engineering programs within North Carolina State University and the Department of Physics and Engineering at Muskingum College followed the same procedure. Thus far, the following steps have been completed:

- List key constituencies relevant to the program.
These included: admissions, students, the department of physics and engineering, supporting engineering faculty and staff, science division faculty, science division coordinator, vice president of academic affairs, alumni, employers, graduate schools, and the Engineering Science Advisory Panel.

The Engineering Science Advisory Panel is yet to be formed but will play an important role in assessing and guiding the program as it moves forward.

- Describe the individuals or groups who will serve as representatives of the constituencies.

As stated by Carter et al., most constituencies are too large to be used as a whole, so suitable representatives have to be identified or some method of polling said constituencies must be employed. Since the engineering science program has an initial start date of fall 2007, the following constituencies were not involved in generating the PEO: students, alumni, employers, and graduate schools. They will be indirectly involved through the Engineering Science Advisory Panel. The constituencies that did participate and the methods of enlisting their aid are shown below.

<table>
<thead>
<tr>
<th>Constituency</th>
<th>Methods for Gaining Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department of Physics &amp; Engineering</td>
<td>Email and Department Meeting</td>
</tr>
<tr>
<td>Faculty &amp; Staff</td>
<td></td>
</tr>
<tr>
<td>Supporting Engineering Faculty &amp; Staff</td>
<td>Email and Meeting with Chair</td>
</tr>
<tr>
<td>Science Division Faculty</td>
<td>Email and Science Division Meeting</td>
</tr>
<tr>
<td>Science Division Coordinator</td>
<td>Email and Meeting with Chair (if needed)</td>
</tr>
<tr>
<td>Vice President of Academic Affairs</td>
<td>Email and Meeting with Chair (if needed)</td>
</tr>
<tr>
<td>Vice President of Enrollment</td>
<td>Email and Meeting with Chair (if needed)</td>
</tr>
</tbody>
</table>

- Analyze the institutional mission as it is related to the program.
- Describe the relationship between the PEO and the needs of key constituencies and the institutional mission.
- Describe the relationship between the PEO and other ABET criteria.

These three steps will require repeated iterations before we are satisfied with them. We have taken an initial pass while devising the PEOs, distributed them to available constituencies for feedback, and will revisit them as new faculty join the team and the program becomes more well-defined.

- Devise a step-by-step plan for generating objectives.

The detailed plan that was followed last year for generating PEOs is shown below.

<table>
<thead>
<tr>
<th>Constituency Task</th>
<th>Date</th>
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<tbody>
<tr>
<td>Department of Physics &amp; Engineering Faculty &amp; Staff Will Generate PEO</td>
<td>July 19th</td>
</tr>
<tr>
<td>Distribute PEO to Supporting Engineering Faculty &amp; Staff</td>
<td>July 19th</td>
</tr>
<tr>
<td>Deadline for Supporting Engineering Faculty &amp; Staff to Provide</td>
<td>August 16th</td>
</tr>
<tr>
<td>Feedback on PEO</td>
<td></td>
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<tr>
<td>----------------</td>
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<tr>
<td>Distribute PEO to Science Division Faculty</td>
<td>August 23rd</td>
</tr>
<tr>
<td>Deadline for Science Division Faculty to Provide Feedback on PEO</td>
<td>September 6th</td>
</tr>
<tr>
<td>Distribute PEO to Science Division Coordinator</td>
<td>September 13th</td>
</tr>
<tr>
<td>Deadline for Science Division Coordinator to Provide Feedback on PEO</td>
<td>September 27th</td>
</tr>
<tr>
<td>Distribute PEO to Vice President of Academic Affairs</td>
<td>October 4th</td>
</tr>
<tr>
<td>Deadline for Vice President of Academic Affairs to Provide Feedback on PEO</td>
<td>October 18th</td>
</tr>
<tr>
<td>Distribute PEO to Vice President of Enrollment</td>
<td>October 25th</td>
</tr>
<tr>
<td>Deadline for Vice President of Enrollment to Provide Feedback on PEO</td>
<td>November 8th</td>
</tr>
<tr>
<td>Post PEO on Department of Physics &amp; Engineering Web Site</td>
<td>November 15th</td>
</tr>
</tbody>
</table>

- Produce a final list of objectives based on a variety of inputs.

Our PEOs are listed below and have been published on our website\(^5\).

Graduates of the Engineering Science program offered by the Department of Physics and Engineering at Muskingum College will be:

1. prepared to engage in and recognize the need for life-long learning.
2. broadly educated in the liberal arts: understanding the foundations of knowledge and inquiry about nature, culture, self and society; mastering core skills of perception, analysis, and expression; cultivating a respect for the truth; recognizing the importance and the diversity of historical and cultural contexts; and exploring connections among formal learning, citizenship, and service to our communities.
3. broadly educated in the fundamentals of engineering, modern physics, computational science, and material science in preparation for working in areas where traditional science and engineering disciplines overlap.
4. prepared to apply effectively, responsibly, and contextually their analytical, experimental, computational, and design knowledge and skills as participants in multi-disciplinary teams.
5. prepared to compete for entry-level engineering positions and further their engineering education in graduate school.

- Process log, recording all activities related to determining PEO.

Obviously, this is an ongoing process that we are fully engaged in.

Future Plans

With successful search for and hiring of our first engineer, we are prepared to move forward with this process in preparation for our program's first year. In the coming months we hope to accomplish the following steps:

- Devise a procedure for periodic review of the objectives.
• Generate reports for each of the review cycles.
• Describe the program as a working system of interrelated parts leading toward continual improvement of the program.
• Continue the process log (Item 8), recording all assessment activities related to Criterion 2.

Program Outcomes

Currently, we are working on the development of our program outcomes. This is an ongoing process as well and we will likely use our new engineer's input to revise as needed. While most programs appear to state the outcomes published by ABET verbatim, we have opted to further define outcomes related to our program. We are using the EC 2000 Outcome Attributes by Besterfield-Sacre et al. as a guide in this process\(^6\)\(^7\).

We also have a great deal of work to do laying the foundation for the curricular threads identified above. It is our hope to employ novel and successful methods for integrating these threads into our curriculum for the purposes of producing a program and graduates that embody the principles and standards of excellence outlined by ABET criteria and our institution's mission statement. We look forward to reporting on these activities in future reports.

References


