AC 2012-4721: NEWBERRY AND FARISON REDUX: A SURVEY OF GENERAL ENGINEERING

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Newberry and Farison Redux: A survey of general engineering

For some time now it has been conventional wisdom that multidisciplinary or interdisciplinary activities will be increasingly important in the future. For example, the ABET General Criteria has contained outcome (d), which is “an ability to function on multidisciplinary teams” for close to two decades now.   Here we will explore that question using some quantifiable evidence.   We will conclude that one major option for the inclusion of multidisciplinarity into undergraduate education is not being adopted in spite of this conventional wisdom.   We conclude by briefly considering why this is the case.

Methodology

Here we will use the ABET accreditation process as a source of data that allows us to explore how this common wisdom is affecting the nature of engineering undergraduate education. The ABET process uses two types of criteria: the general criteria and program specific criteria. The general criteria must be satisfied by all engineering programs, including programs that are aimed at a specialty field or discipline.   In contrast, each of the program specific criteria focuses on a specific engineering field or discipline. To be accredited in one of these specific fields, a program must satisfy both the program specific criteria and the general criteria as well. However, ABET has long allowed programs to seek accreditation under just the general criteria alone. In fact, this is the 8th most common “category” for ABET accreditation with larger numbers of accredited programs than most program specific areas. We use this data here.

The ABET data on accreditation will be supplemented by several other sources. First, the website of every pertinent school was accessed and the description offered there of the program’s curricula was examined. This examination was guided by the earlier work of Newberry and Farison[1] who performed a similar study and classified these engineering programs into three types: flexible, instrumental and philosophical. In addition, data on engineering enrollments and graduation rates was obtained from an ASEE survey[2]. Lastly, data on the institutions themselves in terms of total enrollments, admissions processes, general stature and mission (e.g. regional university, national liberal arts college etc.) and basic organizational type (public, private or private with a religious affiliation) was extracted from a recent survey of colleges and universities[3]. Additionally, the author visited 7 of the 41 schools that currently accredit as a general engineering or engineering science program.

Newberry and Farison’s survey

In 2003 Newberry and Farison presented a survey of engineering programs that did not accredit under any of the program specific categories. In addition to surveying programs that were accrediting in this manner in about the year 2001, they surveyed programs that had accredited this way in the past.   Their data led one to conclude that as of 2001, undergraduate engineering education generally provided only disciplinary paths to the student.

Newberry and Farison did make some conclusions about how these programs were used. Often general engineering programs are used as an incubator for discipline specific programs. In such cases, when the discipline specific degrees come on line, the general degree is often dropped. General degrees are also commonly found at smaller institutions where it is likely that there will be only a single accredited engineering degree and department. In most of these cases the program is of a type that Newberry and Farison categorized as instrumental. Instrumental programs commonly feature a set of concentrations or emphasis areas which are designed to provide an educational experience that closely resembles a set of discipline specific degrees sharing a common core. At larger schools, general degrees are likely to be used to allow students to individually blend engineering coursework from various different disciplines in a highly multidisciplinary fashion. Newberry and Farison categorized these degrees as flexible degrees. Almost everywhere where this is done though, the flexible degree is a special purpose degree, unassociated with a faculty dedicated to it and often with enrollments less than 10. At only a few institutions do you find departments, faculties and degrees that are devoted either to providing a highly flexible degree or a degree which is philosophically devoted to the value of breadth across engineering. This last type of degree was categorized by Newberry and Farison as philosophical.

Data

In Table 1, we provide a list of schools that had programs that were accredited as a general engineering or engineering program by ABET in the 2010/2011 academic year. We also show how Newberry and Farison categorized the program if they included it in their 2003 paper. In addition to classifying programs that have come into being since the time of Newberry and Farison, we also revisited all of the surviving programs from their study and independently classified them as well. In almost every instance where the program was independently classified in both surveys, we came to the same conclusion as did Newberry and Farison. This indicates both reasonable consistency between the two surveys and constancy in the degree programs themselves.

Table 1. Engineering and General Engineering Programs. The letter “f’ denotes a flexible program, the letter “i” an instrumental program and the letter “p” a philosophical program. NA denotes a program that became accredited in between the two surveys.

Institution	Date of initial accreditation	Newberry & Farison Classification	2011 Classification
Dartmouth	1936	p	p
University of Illinois	1936	f	f
Swarthmore	1936	p	p
Stevens Institute of Technology	1936	f	f
Harvey Mudd	1962	p	p
Walla Walla University	1971	i	i

Institution	Date of initial accreditation	Newberry & Farison Classification	2011 Classification
Michigan Technological University	1975	f	f
University of Tennessee at Chattanooga	1977	i	i
McNeese State University	1981	i	i
Montana Tech of the University of Montana	1981	i	i
Colorado School of Mines	1983	i	i
Arkansas State University	1987	i	i
Calvin College	1987	i	i
LeTourneau University	1988	i	i
Baylor	1989	f	f
Grand Valley State University	1990	i	f
Mercer University	1990	i	i
Dordt College	1991	i	i
Messiah College	1994	i	i
Oral Roberts University	1994	i	i
Trinity College, CT	1994	i	i
Geneva College, PA	1995	i	i
John Brown University	1997	i	i
Texas Christian University	1997	i	i
University of Tennessee at Martin	1999	i	i
Hope College	2000	p	i
Olivet Nazarene University	2000	i	i
Roger Williams University	2000	i	i
MIT	2002	NA	f
George Fox University	2003	NA	i
Southern Utah University	2003	NA	p
Robert Morris University	2004	NA	i
University of Southern Indiana	2004	NA	p
Union University, TN	2004	NA	i
Franklin W. Olin College of Engineering	2005	NA	f
Andrews University	2006	NA	i
Colorado State University, Pueblo	2007	NA	p
East Carolina University	2007	NA	i
Elizabethtown College	2007	NA	i
Arizona State University Polytechnic	2008	NA	f
Marshall University	2008	NA	i

Let's summarize the data. Since Newberry and Farison's survey, 13 schools have added general engineering programs. Three of these are philosophical, three are flexible and seven are instrumental. 28 of the 34 programs found in operation by Newberry and Farison were still in operation in 2010/11. All six of the programs that disappeared were classified by Newberry and Farison as flexible programs. The total numbers and distributions of the programs are shown in

Table 2. No significant shift in the statistics beyond a growth in total number of programs is apparent.

Table 2. Summary Statistics for General Engineering Programs

Survey	Total number of schools	philosophical	% flexible	% instrumental
Newberry & Farison	34	12%	29%	59%
Present study	41	15%	20%	66%

In most instances, the new programs represent the only ABET accredited degree offered at the institution. The trend noted by Newberry and Farison that the instrumental programs fit a different institutional profile, with smaller campuses and a greater likelihood of a religious affiliation is holding true as well.

Newberry and Farison also discussed engineering science programs and suggested that they were in a state of relative decline. The decline has continued. There were 14 engineering science programs in operation at the time of their survey with several apparently headed towards elimination. In fact, only 9 of the 14 were still in operation in 2011/11, with only one new engineering science program being added in the interim.

The most important data driven conclusion however is found by asking about the "missing" schools. Almost all engineering schools are missing from the data set. Schools with strong existing disciplinary based engineering programs usually do not have these broader based engineering degrees and they are not adding them to their degree mix. Since 2002, only two schools with significantly sized existing programs have added a general degree: MIT and Arizona State University. At Arizona State, the new degree was the first engineering degree to be created on the Polytechnic campus, a new campus located approximately 20 miles away from the Tempe campus which houses the existing engineering programs. Only the MIT program therefore actually represents an existing engineering department or college adding a general degree.

Let's consider some other numbers. Newberry and Farison found 48 general engineering programs or engineering science programs out of a total of 1661 engineering programs in the US. That is drawn from a base of 347 institutions offering one or more accredited programs. So, at roughly 90% of US schools offering ABET accredited degrees, there was no option extended to the student except for an accredited discipline specific degree. In 2010, the overall ABET data (which does include some international schools) had 51 programs out of a total of 2055 at 424 institutions. When one factors in the above descriptions of the small enrollments in most flexible programs, and the fact that an instrumental program often resembles the discipline specific options, perhaps 98% of engineering undergraduates in the US are not offered a real option at a general, multi- or interdisciplinary engineering education.

Disciplinarity, Multidisciplinarity and Interdisciplinarity

Multidisciplinarity is a usefully vague term. We often use it interchangeably with terms such as interdisciplinarity or transdisciplinarity. Here we will make a distinction between multi- and inter- as prefixes. In a multidisciplinary approach, the issue involves the differences between the disciplines. Two or more fully specialized disciplinary experts are combining nominally separate understandings. In an interdisciplinary approach, the issue involves common ground shared by the different disciplines. Interests, knowledge and methods may be shared by experts in what are nominally disparate disciplines. However, as Menand[4] notes, all of these terms matter only because we have disciplines. So we start our discussion by reviewing the historical development of the engineering disciplines.

There were no academic disciplines at all involved in the organization of the American college prior to the Civil war. All students took the same curriculum and received the same degree, a Bachelor of Arts degree. In what is sometimes called the big bang of American higher education, the fifty year period running roughly from 1870 to 1920, various academic disciplines across the university came into being, along with an associated array of doctoral programs, specialized degrees, academic majors and professional societies. This was also the period in which the modern technological society was created. So, at the beginning of this big bang, the differentiation between civil and mechanical engineering was sometimes recognized but the terminology "mechanical engineer" was still uncommon. For example, the Morrill Land Grant Act of 1862 referred to the "mechanic arts". With regard to electrical engineering, in 1870 Maxwell had just noted the theoretical possibility that electromagnetic waves might exist but Hertz had not experimentally demonstrated their existence and no one even suspected that electrons exist. The only commonly used electrical technology was the telegraph. Similar comments can be made for the other major engineering technologies and fields. By the end of this big bang however, most of the major engineering disciplines had come into being along with academic departments and degrees and national professional societies.

As we are using accreditation data here, we should note that the accreditation of engineering programs started after this big bang. This means that the accreditation of engineering programs started after the creation of a set of engineering subfields or disciplines. The ancestor of what we do today, the Engineers Council for Professional Development or ECPD was established in 1932 and just as is the case with its descendant ABET, it was an organization of organizations. ECPD was created through "a joint effort of the engineering schools, the professional societies and the licensing boards" [5]. As a result, while the possibility of a more general engineering degree has always been recognized in accreditation, from the outset engineering accreditation has generally assumed that students normally are pursuing a curriculum that pursues a specific discipline and allowed for a specific national organization defined in a disciplinary manner to guide the accreditation effort for that discipline.

As ABET outcome (d) exists, we know that all ABET accredited degrees must have a plan for developing graduates who can function on multidisciplinary teams. The data presented here shows that we are almost always addressing this outcome inside of a disciplinary setting however. The backdrop for such efforts is well understood. Sheppard et al.[6] recently conducted a national survey of engineering education for the Carnegie Commission. They described engineering degrees as possessing "a remarkably homogenous curriculum and pedagogy". They describe this curriculum as a building block curriculum, where the four main building blocks are analysis, laboratory, ethics and design. The first order of business in these degrees is to establish disciplinary expertise, to deliver technical knowledge to the student. Sheppard et al. note that the portion of the degree that is most clearly related to building broad understanding, the general education requirements, is viewed by engineering faculty as a hurdle faced in the delivery of technical knowledge. It is interesting to note that electives do not appear in Sheppard et al.'s discussion. Indeed, the discipline specific engineering degree is often designed to be as maximally specialized as is possible. The student takes the minimum amount of general education courses required by the institution, the ABET minimum of mathematics and science and then every other credit is required to be an engineering credit, usually lying in the engineering discipline of interest. Normally, there are no general or free or unrestricted electives, courses where the student can adjust the overall depth vs. breadth balance of the degree by choosing any course they want: social science, humanities or more engineering if they so desire.

This brings us back to Menand's observation that a discussion of multi- or interdisciplinarity assumes the existence of disciplines. While we have not surveyed the issue of how an ability to function on a multidisciplinary team is formed in the context of a discipline specific degree, some observations are possible. In these degrees, we organize the curricula in manners which emphasize the differences between electrical, mechanical and civil engineers. Then, having achieved a modicum of success in the discipline of interest, we worry about multidisciplinarity. For example, we worry will be that our disciplinary expert might not be able to communicate with other disciplinary experts. The ABET outcome in question is pursued by adding in a requirement for courses or experiences in which this disciplinarily defined student must interact with other people who do not share the same disciplinary identity. While it is possible to develop multidisciplinarity in such an approach, in terms of the distinction introduced earlier it will be multidisciplinary but not interdisciplinary. The entire approach emphasizes developing and then understanding differences between disciplines and de-emphasizes the possibility that electrical, mechanical and civil engineers are alike.

It is in this regard that the continuing decline of engineering science programs is of interest. As Newberry and Farison note, engineering science appeared on the scene in the 1950's. Engineering science was part of the famous Grinter report on engineering education which argued that a scientific foundation in subjects such as mechanics, electrical circuits and electronics, materials and thermodynamics should be required of all engineering graduates. Secondly the term engineering science was used in the process of defining the alphabet soup of federal agencies which funded scientific research. What then happened is that a set of engineering science programs appeared at universities that already had the normal discipline-specific degrees in place. These programs survived for a while and then declined. Newberry and Farison suggest that there were two main factors for the decline in engineering science programs. First, as federal funding for research in the conventional disciplines became secure; little competitive advantage in attracting funding was associated with an engineering science program. Secondly, many practicing engineers complained that these engineering science courses were not that useful in engineering practice. (It is interesting to note that the Grinter report actually called for a curricular investment in "case studies" that was equal to the curricular investment in engineering science. It also called design the signature feature of engineering.)

The implications though of a rise and fall in engineering science programs is that there was a movement towards an undergraduate program that emphasized a common core to engineering that has since declined. In the terminology we use here, this was a movement towards an interdisciplinary approach which stressed things that are shared across the disciplinary boundaries. The decline in engineering science then can be viewed as part of a broad trend away from interdisciplinary thinking about engineering education.

We have defined interdisciplinarity here in a way that makes it something that could naturally be pursued in the context of a general engineering degree, particularly those that have a philosophical bent. The dominance of discipline based thinking in engineering education is further emphasized when we realize that most schools that accredit as a general engineering program are instead instrumental programs. Even under this accrediting umbrella, there is an apparent reluctance to be interdisciplinary.

Why is this so?

We now ask why engineering is deeply embedded in a disciplinary approach to the virtual exclusion of any other approach.

One factor is the perception that the common wisdom about either multidisciplinarity or interdisciplinarity is wrong when viewed in the context of the job market entered by the recipient of a bachelor's degree. It is argued that industrial advocates for multidisciplinarity are extremely highly placed in the corporate hierarchy while those lower down who actually hire engineering graduates are focused on immediate needs and find the discipline specific degrees to be useful. It is likely that this tendency is real. However, it is difficult to imagine that 98% of the entry-level engineering jobs that require a bachelor's degree are worried aligned on disciplinary boundaries that may have been set a century ago. We believe that what is happening is that these disciplines are being used as shorthand for specific skills. In fact, many advertisements do not cite any specific type of engineering bachelors degree but instead describe such skills. Also, the very same employers clearly know that the M.S. degree exists, with its even more disciplinarily specialized knowledge base, and they could look for M.S. candidates instead of freshly minted B.S. candidates if high levels of disciplinary specialization were truly critical.

The next factor that might be noted is the engineering professor. Engineering professors share in the general professionalization of the professoriate that grew across the entire academy in the latter portion of the 19th century and the first portion of the 20th. There have been several interesting discussions of this in the context of the humanities published in recent years[7-9]as well as in the natural sciences.[10,11] The general conclusion is that this professionalization tends to breed hyper-specialization and an emphasis on technical proficiency at the cost of deep thought. When one examines the characteristics commonly cited for a profession, which include having members of the profession control both entry into the profession and standards of professional conduct, in many ways a better case can be made that the engineering professors in a specified discipline form a professional grouping than can be made for the professionalization of engineering in general. Most engineering schools resemble a set of cooperating faculty guilds that tend to respect each other's turf.

A last factor is the pipeline metaphor that engineering faculty apply to college education. Here we indeed differ from our colleagues in the liberal arts who are more likely to view college as an exploration and to argue that one goes to college to discover what interests you and where your talents lie. In engineering, we instead assume that the student has already discovered their interests and talents. We assume that this happened before they enter the four-year program of study. We assume that as a result the student has decided that they wish to be an engineer and that their sole purpose in pursuing the degree is preparation for engineering practice or engineering graduate school. The pipeline metaphor reinforces our tendency to specialization. We assume that specialization is what the student wants.

Conclusion

The data indicates that the general curricular organization of undergraduate engineering programs is not meaningfully moving towards a more multidisciplinary format. Disciplinary degrees and curricula remain the norm. The general engineering model is used at new programs during a startup phase, and at smaller institutions. It is rarely employed at the larger engineering schools in any format other than a boutique degree.

As there is an accreditation requirement, we know that all ABET accredited degrees have plans and approaches for fostering a graduate who can function on a multidisciplinary team. This however is being done inside of a disciplinary setting. The emphasis is on developing a disciplinary identity and then some means of addressing the ability to team with people educated in another discipline is introduced.

The accreditation process though allows for other approaches in which the disciplinary identity is not emphasized. Instead, the program could be more interdisciplinarily focused on what the various fields of engineering share. In spite of the common wisdom about the importance of multidisciplinarity, the evidence associated with accreditation suggests that if anything undergraduate programs that stress an interdisciplinary or multidisciplinary approach are becoming rarer. There evidently are powerful barriers in place against such degrees. We speculated that these barriers include the professionalization of engineering professors as specialists, the assumptions that engineering professors make about the job market for graduates of their program and assumptions that engineering professors make about when and why students enter the degree program in the first place.

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