AC 2011-39: THE EVOLUTION OF ENGINEERING AND ENGINEERING TECHNOLOGY EDUCATIONAL PROGRAMS IN THE UNITED STATES

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The evolution of engineering and engineering technology educational programs in the United States

Abstract- Since the turn of the century, there have been about the same number of programs in the mechanical, electrical civil, chemical and industrial disciplines to be newly accredited by the Accreditation Board for Engineering and Technology (ABET) in engineering versus engineering technology. According to ABET, these disciplines represent the majority of the total current number of engineering and engineering technology programs they oversee. However, considering only newly accredited programs since 2000, there have been considerably more engineering programs than engineering technology programs to receive their first review by ABET. In addition, while there have been some small, recent enrollment increases in engineering programs nationwide, these programs typically suffer from low enrollments and high operating costs.

The engineering disciplines which show anticipated job growth greater than graduation rates are environmental, industrial, electronics and mining engineers. A review of the five primary curricular areas of engineering shows four of the five are forecast to graduate nearly 224,000 more engineers than will be needed. Administrators should not initiate programs in electrical, mechanical, civil, or chemical disciplines nor most other disciplines of engineering. Environmental, industrial, electronics and mining engineers are forecast to be the strongest engineering areas in which to invest from a standpoint of jobs available to graduates.

In the engineering technology job fields, all but mechanical engineering technology are forecast to need more graduates than will graduate. Engineering technology degrees will be less risky to start than engineering degrees due to the generally larger student to program ratios.

Keywords: engineering enrollment, engineering accreditation, engineering technology enrollment

Introduction

“Improvise, adapt, overcome” is a credo that engineering and technology educational program administrators at American universities may need to adopt. To maintain the quality of higher education in the United States, administrators must strategically plan to optimize programs which may be successful and discontinue programs which are not successful. They must improvise in a time when public funding of higher education is declining, adapt programs to optimize their operations, and overcome the natural effect of diminished quality which is expected during periods of inadequate operational funding.

“When this recession ends, campuses should not restore funding to every program that has been cut. Instead, they should begin preparing for the next downturn, since, if there has been a single lesson coming out of the last two years, it is that we have not defeated the business cycle” [9]. Newfield also suggests establishing programs that enhance productivity without sacrificing quality. How does an administrator of a higher education program accomplish this task? A natural response is to benchmark the world’s top universities, most of which are in the United States, but a review of the financial status of universities on the top twenty list [11] reveals a general lack of reliance upon public funding. Harvard, Cambridge, MIT, Yale, Cornell rely heavily on endowments for operational funding. Yale's endowments, for instance, provided 46 percent of total operating revenue last year [5]. In addition, tuition and fees at the top universities might go as high as their presidents and operating boards wish without impacting the number of students who attend. Administrators on the ground at public universities generally have four options for funding: public funding through their state government; grant funding from the Federal government and private institutions for research; endowments and donations; and tuition.

Public funding of universities by state governments has been flat or falling for more than twenty years [9,13]. State governments generally can no longer be relied upon to provide necessary funding for educational programs when the economy is poor. This was not the case in the 1980s and before [3]. The same principle applies to endowments and donations. When the economy is slow, donations to universities are generally lower [8]. With reduced state funding and lower donations received during hard economic times, obtaining grant funding and raising tuition are the only alternatives for maintaining the stability of educational programs.

Raising tuition is often dependent upon program enrollments. State governments often set enrollment minimums for programs. As an example, North Carolina funds sixteen university campuses based upon a student contact hour model [2]. North Carolina uses four category levels of funding instructional positions:

Category I	708.64 SCH
Category II	535.74 SCH
Category III	406.25 SCH
Category IV	232.25 SCH

The Category IV level includes higher priority programs such as engineering and nursing. The lowest category includes English, social sciences, mathematics, and philosophy. For instance, a professor teaching multiple sections of a three credit hour English 101course needs 708.65 divided by 3 which equals about 236 students total, or about 59 students per class if four classes are taught, to justify his position financially. A nursing or engineering professor only needs 78 students or about 20 students per section for four sections. If a program administrator managing an engineering (Category IV) or an engineering technology (Category III) program is facing enrollment levels below the published funding guidelines, tuition increases may be problematic.

Faculty of engineering programs often receive research grants. One Canadian study found that 80 percent of researchers in engineering received funding for research for at least one project versus 55 percent for the faculty in basic medical sciences programs [7]. Administrators must be careful about the research they perform. Newfield [9] found that "Extramural sponsors of research never pay the full costs of that research… and private sponsors generally require it to pay the most". While research may provide additional funding for operations, this source of funds may also be affected by the economy. In addition, facilities to perform research must be available to the researchers. If facilities are not available, it may be impractical to apply for research grants unless the grant includes funding for the equipment or facilities needed to perform the research. For engineering and engineering technology program administrators, a possible best long term strategy may be to assure program sustainability by providing quality programs which maintain adequate enrollment levels and to apply for research funding from Federal agencies and private sources.

For the engineering and technology fields, post-secondary educational programs there are several sources of information for an administrator to refer to provide programs with acceptable enrollment levels. The outlook for engineering jobs is positive for the next ten years according to the Bureau of Labor Statistics [1] and salaries for engineers are typically in the $80,000 to $100,000 per year range[4]. The Accreditation Board for Engineering and Technology and the Bureau of Labor Statistics provide information which may be used to determine the best program concentrations.

Accreditation Board for Engineering and Technology

According to their website, the Accreditation Board for Engineering and Technology (ABET) "serves the public through the promotion and advancement of education in applied science, computing, engineering, and technology." They "provide, operate and maintain an independent and objective accreditation system of the highest quality and effectiveness." They accredit engineering programs which may be described as "the art of applying the principles of mathematics and science, experience, judgment and common sense to make things which benefit people. Engineering technology programs are characterized by their focus on application and practice, and by their approximately 50/50 mix of theory and laboratory experience" [6].

ABET provides statistics about accredited programs. They reported 1964 bachelor degree programs at 397 institutions accredited by the Engineering Accreditation Commission (EAC) as of October, 2009, and 651 associate and bachelor programs at 230 institutions accredited by the Technology Accreditation Commission (TAC). It appears more engineering programs are becoming accredited, while accreditation of engineering technology programs seems to be on the decline. The primary curricular areas of engineering and technology which are accredited are electrical, mechanical, civil, chemical and industrial [12].

The number of graduates from ABET accredited programs from 2004 to 2009 is shown in Table 1. In 2009, there were 74,387 bachelor graduates from engineering programs accredited by ABET, about 38 graduates per program on average . During the same period, there were 6044 bachelor graduates from engineering technology programs or about 77 graduates per program, see Table 2.

The number of graduates from engineering technology increased while the number of programs decreased, but the growth in engineering graduates was just over two percent while the number of programs increased by almost seven percent [12]. It appears there are more engineering programs competing for fewer students.

The Bureau of Labor Statistics

A report published by the Bureau of Labor Statistics (BLS) entitled, "Occupational employment projections to 2018" provides a point for analysis. In the engineering field, there are forecasted to be 531,300 job openings from 2008 through 2018 due to growth and worker replacement. In the engineering technology field, there are expected to be 124,900 total openings. The BLS categories are slightly different from the ABET categories.

Table 1: Engineering Graduates from 2004-2009. Source Profiles of Engineering and Technology Colleges, 2009.

Bachelor's Degrees	2004	2005	2006	2007	2008	2009
Aerospace	2,232	2,371	2,722	2,788	2,930	3,057
Architectural	590	722	631	625	646	723
Biological/Agricultural	601	635	646	659	623	631
Biomedical	2,019	2,410	2,917	2,969	3,237	3,644
Chemical	4,801	4,521	4,452	4,551	4,850	5,185
Civil	8,142	8,247	8,935	9,402	10,132	10,508
Civil/Environmental		212	291	445	464	558
Computer	5,838	5,455	4,901	4,046	3,808	3,394
Computer Science (inside eng.)	9,156	8,419	7,330	6,446	5,964	5,652
Electrical	12,500	12,459	11,915	11,467	10,790	9,859
Electrical/Computer	2,700	2,924	2,825	2,425	2,216	2,194
Engineering (general)	1138	1179	1176	1246	1160	1246
Engineering Management	302	303	238	274	331	309
Eng. Science &Eng. Physics	501	383	431	460	472	431
Environmental	576	522	437	454	486	503
Industrial/Manufacturing	3790	3647	3664	3503	3367	3510
Mechanical	14,182	14,947	16,063	16,701	17,324	17,375
Metallurgical & Materials	817	840	909	963	1095	1035
Mining	85	92	120	119	153	190
Nuclear	202	275	342	402	415	378
Other	2,488	2,724	2,902	2,942	3,211	3,351
Petroleum	233	315	339	428	496	654
Total	**72,893**	**73,602**	**74,186**	**73,315**	**74,170**	**74,387**

If a list of common categories is built, a table of forecast job openings versus degrees awarded will result. See Table 3. Observation of the information provided reveals that the number of degrees awarded multiplied by ten, the time period of the forecasts, then there will be more graduates than jobs.

If the table is further consolidated by calculating the growth rate in college graduates based upon historical data, the result will show there are forecast to be more graduates than there will be jobs in most categories, see Table 4. While it is difficult to directly correlate engineering graduation numbers with BLS categories, engineering and technology program administrators should take care when considering new programs or continuing old ones. The subset of programs shown here represent 602,800 jobs of the total anticipated 656,200. There will be crossover between disciplines, such as

Table 2: Engineering Technology Graduates from 2003 & 2009. Source Profiles of Engineering and Technology Colleges, 2009.

Engineering Technology Degrees		2003	2009
Aerospace		48	7
Architectural		126	88
Civil		479	324
Eng. Technology (general)		683	333
Industrial/Manufacturing		258	342
Computer		223	536
Construction		316	795
Other		1617	924
Electrical		1559	1,328
Mechanical		627	1,367
	Total	5936	6044

Table 3: Engineering & Technology Jobs. Source: Bureau of Labor Statistics, 2010

Employment Title	2008 (X1000)	2018 (X1000)	Total job openings (X 1000)	Awarded degrees, 2009
Aerospace engineers	71.6	79.1	22.3	3057
Agricultural engineers	2.7	3	0.9	631
Biomedical engineers	16	27.6	14.9	3644
Chemical engineers	31.7	31	7.8	5185
Civil engineers	278.4	345.9	114.6	10508
Computer hardware engineers	74.7	77.5	23.5	3394
Electrical and electronics engineers	301.5	304.6	72.3	2194
Electrical engineers	157.8	160.5	38.9	9859
Environmental engineers	54.3	70.9	27.9	1061
Industrial engineers	455.2	519	94.6	3510
Mechanical engineers	238.7	253.1	75.7	17,375
Mining and geological engineers	7.1	8.2	2.6	190
Nuclear engineers	16.9	18.8	5.4	378
Petroleum engineers	21.9	25.9	8.6	654
Aerospace engineering technicians	8.7	8.9	1.8	7
Civil engineering technicians	91.7	107.2	32.8	1119
Electrical & electronic engineering techs	164	160.4	31	1328
Industrial engineering technicians	72.6	77.4	18.5	342
Mechanical engineering technicians	46.1	45.5	8.7	1367

Totals 602800 65803

mechanical engineers performing environmental work, but there will be more engineers than the job market will be able to absorb.

Table 4: Growth of Engineering and Technology Graduates versus Jobs 2009-2018

Employment Title	Total* Bachelor Degrees 2009-2018p	Total Job Openings 2018	Surplus
Aerospace engineers	57941	22300	-35641
Agricultural engineers	6549	900	-5649
Biomedical engineers	101991	14900	-87091
Chemical engineers	48722	7800	-40922
Civil engineers	115820	114600	-1220
Computer hardware engineers	31802	23500	-8302
Electrical and electronics engrs	22259	72300	50041
Electrical engineers	93408	38900	-54508
Environmental engineers	9946	27900	17954
Industrial engineers	34900	94600	59700
Mechanical engineers	202641	75700	-126941
Mining and geological engineers	2041	2600	559
Nuclear engineers	8983	5400	-3583
Petroleum engineers	13983	8600	-5383
Aerospace engineering techs	42	1800	1758
Civil engineering technicians	25097	32800	7703
Electrical and electronic engr techs	12084	31000	18916
Industrial engineering techs	4232	18500	14268
Mechanical engineering techs	30402	8700	-21702
Totals	822841	602800	-220041

*Calculated by taking the number of graduates and applying the average growth rate from historical data and applying the formula $FV=PV(1+i)^n$ for each consecutive year.

Recommendations

The engineering disciplines which show anticipated job growth greater than graduation rates are environmental, industrial, electronic and mining fields. If a review of the five primary curricular areas of engineering which are electrical, mechanical, civil, chemical and industrial is made, four of the five are forecast to graduate nearly 224,000 more engineers than will be needed. Administrators should not initiate programs in electrical, mechanical, civil, chemical disciplines or most other disciplines of engineering. Environmental, industrial, electronics and mining fields are forecast to be the strongest engineering areas in which to invest.

In the engineering technology job fields, all but mechanical engineering technology are forecast to need more graduates than will graduate, but it is assumed that the BLS database includes bachelor and associate degrees whereas the ABET database only reports bachelor degrees in engineering technology. Engineering technology degrees will be less risky to start than engineering degrees due to the generally larger student to program ratios observed in the previous discussion. Even given North Carolina's funding model, technology programs make more sense from a management standpoint than does engineering.

The best programs may be combinations of engineering and engineering technology. For instance, environmental, industrial, electronics and mining engineers are forecast to be the strongest engineering curriculums which will provide jobs for graduates. For administrators who want engineering programs at their institutions, initiating a program in one of these areas in coordination with a similar engineering technology curriculum might provide the best of both worlds. Research funded engineering faculty may work in concert with engineering technology faculty teaching well enrolled courses with acceptable student contact hours thereby providing the necessary state funding to maintain both programs. Administrators at each institution could formulate plans which would synergize their programs. For instance, an environmental engineering program might work in concert with a civil engineering technology (CET) program or even a construction management (CM) program for a specific department. The environmental faculty could apply for research grants and the civil and construction programs could support the department with student contact hours. Some lower level engineering courses might even be integrated into the curriculums of the CET or CM programs.

Conclusion

"When this recession ends, campuses should not restore funding to every program that has been cut. Instead, they should begin preparing for the next downturn, since, if there has been a single lesson coming out of the last two years, it is that we have not defeated the business cycle"[9]. Observation of the data included in this paper seems to support this statement. Well funded, "fat" programs will probably never again be the norm. Faculty of engineering and technology programs have an opportunity to steer their own destiny if administrators will create supportive environments.

Engineering and technology faculty should remain open-minded about the possibilities of a future technology worker surplus in their fields. Administrators of these programs should be cognizant of the job security concerns of their faculty should engineering and technology programs be eliminated. Additional study needs to be done of the jobs outlook in specific engineering and technology fields to provide data that will support sound decision making.

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