Annals of Biomedical Engineering, Vol. 43, No. 8, August 2015 (© 2015) pp. 1713–1715
DOI: 10.1007/s10439-015-1319-2

Biomedical Engineering Accredited Undergraduate Programs: 4 Decades of Growth

I am pleased to continue the series of Biomedical Engineering Society (BMES) presidential editorials in our lead journal, the *Annals of Biomedical Engineering*. With the privilege of this forum, I want to take the opportunity to provide data to document the astounding growth of academic programs in Biomedical Engineering and the number of remarkable students that we are preparing. The focus in this short piece is on ABET accredited undergraduate programs in the US, the students they serve, and the faculty that lead their learning.

The table of ABET accredited undergraduate programs tells an interesting story (data from Ref. 3). In the 1970s, 7 universities had established accredited undergraduate programs in Bioengineering/Biomedical Engineering (referred to hereafter as BME). Although each new department/program has a unique genesis story, several of the early programs developed from Electrical Engineering departments that were focused on measurement and instrumentation. The BME programs were mostly at private universities with schools/colleges of engineering and associated medical schools. The story was similar for many of the 13 new accredited BME programs in the 1980s, with comparable initial conditions, but additional program births from mechanical and materials oriented programs. Only 4 new programs were accredited in the 1990s (see Table 1 with data from Ref. 3).

Note that the Whitaker Foundation was very active from the 1990s until 2006 with an emphasis on biomedical engineering education and the development of departments.[2] The Foundation recognized that in the academy, centers and institutes may come and go, but departments have relative permanence. Whitaker Foundation funding encouraged matching university investments for developing new BME departments and programs.

It should also be noted that programs cannot be accredited until a student graduates with a degree from the program. Only then can the program submit an ABET self-study, after which the program hosts an ABET evaluator. These visits are generally in the autumn; programs are notified of the outcome during the following summer. Thus, in practice, there is at least a 4-year time lag between the degree program initiation and accreditation; generally it is somewhat longer.

These and other factors contributed to an astounding 51 new ABET accredited BME BS programs between 2000 and 2009. Many of these new programs emerged from chemical engineering activities, with a heavy new emphasis on tissue engineering. Many state universities were also represented. Since 2010, 17 additional BME programs have been accredited. As of January 2015, there were 92 ABET accredited BS programs in Bioengineering/Biomedical Engineering.[3]

Financial opportunities, expansion of research applications for engineering methods and techniques to biomedical problems, and the associated eruption of the quantity and quality of quantitative life science investigations have driven the growth of academic BME programs. So, too, has intense student interest.

Chart 1, with data from the American Society for Engineering Education, shows the overall linear population growth of full time undergraduate students in BME ($r^2 = 0.993$), over the past 15 years.[4] During this period, the population of undergraduate students grew by 1593 each year, despite the fact that many programs have had to cap their enrollment based on limitations of faculty size and facilities.

Meanwhile, the growth of tenure/tenure-track faculty is shown in Chart 2, also using ASEE data.[4] It shows linear growth ($r^2 = 0.983$) since 2001, with 66.9 new tenure track BME faculty added each year. These overall numbers show a current student faculty ratio of 19.7:1. This gross calculation needs interpretation: some programs count freshmen, some do not. Some programs include professors of the practice, and these numbers are not captured in the tenure track faculty count. Nonetheless, the overall ratio may be useful for a rough estimate of faculty resources used by the existing programs. Department chairs sometimes discuss aiming for 3–5 BS degrees awarded per faculty member annually, depending on the nature of the department and the spectrum of primary faculty activities between teaching intensive and research intensive.

Unanswered by these charts is the question of what happens to these students once they graduate? In the early years of BME undergraduate programs, the anecdotal expectation was that 1/3 would go to medical school, 1/3 to graduate school, and 1/3 to industry. Unfortunately, although individual programs track graduates, the last reliable summary data from the

TABLE 1. Timeline for growth of ABET accredited BS programs in bioengineering and biomedical engineering.

Duke University	1972	Rose-Hulman Institute of Technology	2005
Rensselaer Polytechnic Institute	1972	Rutgers University	2005
Brown University	1973–2000; 2004	Saint Louis University	2005
University of Illinois at Chicago	1976	University of Alabama, Birmingham	2005
Case Western Reserve University	1977	University of Connecticut	2005
Texas A&M University	1977	University of Texas at Austin	2005
Louisiana Tech University	1978	Lehigh University	2006
Tulane University	1981	Purdue University	2006
Northwestern University	1982	Binghamton University, SUNY	2006
University of Pennsylvania	1982	The George Washington University	2006
Boston University	1983	University of California, Irvine	2006
Marquette University	1983	University of Virginia	2006
The Johns Hopkins University	1983	University of Washington	2006
University of Iowa	1984	Washington State University	2006
Arizona State University	1986	Bucknell University	2007
Syracuse University	1987	Illinois Institute of Technology	2007
University of California, San Diego	1987	Pennsylvania State University	2007
Milwaukee School of Engineering	1988	University of Central Oklahoma	2007
The Catholic University	1988	University of Maryland	2007
Wright State University	1988	Florida Gulf Coast University	2008
Vanderbilt University	1990	Indiana Univ. - Purdue Univ. Indianapolis	2008
University of Miami	1995	Stevens Institute of Technology	2008
The University of Toledo	1998	The University of Memphis	2008
University of Pittsburgh	1999	University of Louisville	2008
Drexel University	2000	University of Southern California	2008
The University of Akron	2000	University of Utah	2008
University of California, San Diego	2001	City University of New York, City College	2009
University of Tennessee	2001	Clemson University	2009
Worcester Polytechnic Institute	2001	Rice University	2009
North Carolina State University	2002	Indiana Institute of Technology	2010
University of Hartford	2002	The Ohio State University	2010
University of Minnesota	2002	Tufts University	2010
University of Rochester	2002	Union College	2010
Virginia Commonwealth University	2002	University of South Carolina	2010
Georgia Institute of Technology	2003	George Mason University	2011
Michigan Technological University	2003	Lawrence Technological University	2011
University of Cincinnati	2003	The College of New Jersey	2011
University of Wisconsin, Madison	2003	University of California, Davis	2011
Florida International University	2004	University of California, Riverside	2011
Oregon State University	2004	University of Rhode Island	2011
Stony Brook University, SUNY	2004	University of the Pacific	2011
University of Michigan	2004	Miami University	2012
Washington University	2004	University of Illinois at Urbana-Champaign	2012
Western New England University	2004	University of Maine	2012
Columbia University	2005	Wichita State University	2012
New Jersey Institute of Technology	2005	University of California, Los Angeles	2013

American Institute of Medical and Biological Engineers (AIMBE) Academic Council survey results are somewhat stale. Those data are from the 2006–2007 academic year, when programs pooled data from 1352 graduates. The results showed 41% of the students entering industry, 35% entering graduate school, 16% entering medical school, and 8% other (seeking job, unknown, etc.). Outcomes vary based on the university, location (urban or rural), program emphasis, and they have changed over time. These data may nevertheless give a useful ''rule of thumb'' for universities considering the addition or expansion of undergraduate BME programs, until fresh data are collected.

Of course, the linear growth of recent history cannot continue indefinitely. The academic roots for most programs come from universities with colleges/schools of engineering and/or colleges/schools of medicine. It appears that there are approximately 320 colleges/schools of engineering in the US offering BS engineering degrees and 121 colleges/schools of medicine. Most, but not all, universities with colleges/schools of medicine also have colleges/schools of engineering. So, with 92 accredited programs already, one can guess that over the next 25 years, the total number of ABET accredited undergraduate programs in the US may rise to a total of 150–175?

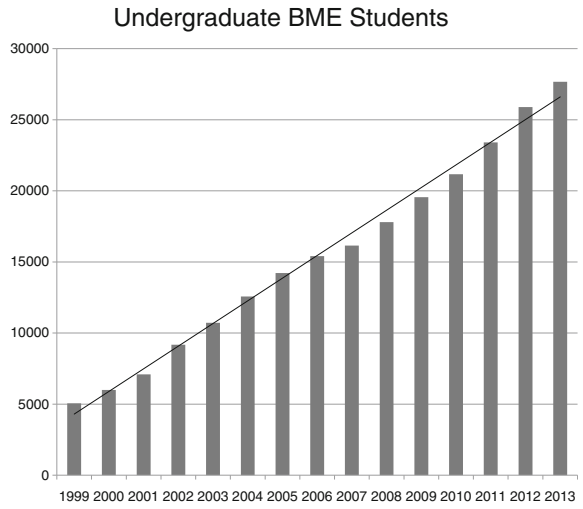

CHART 1. Linear growth of undergraduate enrollment in BME over the past 15 years; an increase of 1593 new students per year.

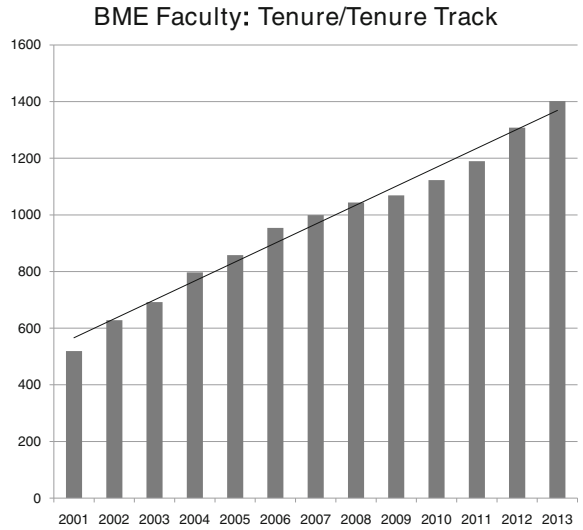

CHART 2. Linear growth of tenure/tenure track BME faculty; an increase of 67 new faculty members per year.

Finally, the US Department of Labor Statistics projects job outlooks for many occupations. The current outlook for Biomedical Engineers is for 27% job growth between 2012 and 2022, over twice the overall outlook of 11% for all occupations.[1] Time will tell!

Until then, it may be worth pausing to note the great success that has accompanied the launch of our accredited undergraduate interdisciplinary academic programs since 1972.

ACKNOWLEDGMENTS

I very much appreciate the comments that Peter G. Katona made on an earlier draft of this note.

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