Why a Bachelor's Degree in Biomedical Engineering Technology and Why Now?

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ABSTRACT

There is presently a shortage of qualified Biomedical Engineering Technology (BMET) job applicants. This trend will be exacerbated by the approaching retirement of many of the baby-boomer BMET professionals. As a result of these shortages, hospital-related employers often hire people with a strong electronics background but a limited or absent specialization in BMET. Many of these employees are graduates of two-year Associate Degree Electronic Engineering Technology (EET) or closely associated BMET programs. Some applicants have a military electronics background. Only a handful of applicants come from the very few Bachelors Degree programs such as the program at East Tennessee State University. Why would someone enter the Bachelors program in BMET when he or she could enter the BMET profession in half the time and for significantly less costs? The answer is expanded professional and financial opportunities during his or her professional career.

The Biomedical Engineering Occupation Spectrum

The success and future of academic programs in engineering technology are often related to the employability of its graduates.[1] The U. S. Department of Labor expects biomedical engineering jobs to increase faster than the average for all occupations through 2010.[2] Changes in population influence the demand for goods and services, and U. S. population is expected to grow by 24

million over the 2000-2010 period.[3] Healthcare services (including healthcare services, hospitals, and offices of health practitioners) education and training will add 2.8 million jobs as the demand for healthcare increases due to an aging population and longer life expectancies. Nearly three quarters of the job growth will come from three groups of professional occupations: computer and mathematical occupations, healthcare practitioners, technical occupations, and education, training, and library occupations.

The development of the computer and all of its associated parts--hardware, software, sensors, and algorithms--has provided an escalating wealth of technological opportunities and advances.[4,5,6] Whereas the early computer-generated technological advances were simple and often linear exchanges of manual applications for computer applications (ledger versus printout, analog display versus digital display, etc.), new technological advances are complex and often characterized by new knowledge. With each new advance in technological knowledge, there is a corresponding demand for new, increasingly computer-literate professionals.

Astounding progress has been made in medical science over the last half-century.[5] Although often overlooked or understated, much of the progress in medical science has been, and continues to be, directly related to engineering advances. The linkage between biomedical engineering and medical science is exemplified by the introduction of an increasing number of the most varied, frequently complex and sophisticated, electro medical devices and equipment into everyday medical practice.

The Whitaker Foundation[7] defines biomedical engineering as "a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and

clinical practice." The biomedical engineering field is exceptionally multidisciplinary. Examples of subdisciplines include biomedical instrumentation, medical imaging, biological signal analysis, medical informatics, clinical engineering, biomechanics, rehabilitation engineering, prosthetic devices and artificial organs, biomaterials, biosensors, cellular and tissue engineering, biological transport phenomena, physiological modeling, biological effects of electromagnetic fields, to name but a few. Although biomedical engineering is primarily interested in engineering principles and concepts, knowledge of biological and medical principles is significant. Those technicians and engineers associated with specific medical processes may be as well informed as the doctors.

The engineering occupational spectrum model has been around for decades and consists of crafts persons, technicians, technologists, and engineers as shown in Figure 1. The spectrum can be transferred to biomedical engineering without any loss in generality. This model is replete with argumentative discussions related to names, designations, and titles.[8] The important point is that biomedical engineering provides hospitals, industry, government, and the engineering

CRAFTSPERSON		TECHNICIAN	TECHNOLOGISTS		ENGINEER			SCIENTIST
VOCATIONAL EDUCATION		ENGINEERING TECHNOLOGY			ENGINEERING			
AAS	AS	AET	BSET		BSE	BS	MS	PhD
Repair Assemble Operate Construct	Testing Service Maintenance Routine Analysis	Quality Assurance Tech. Sales Maintenance	Manufacturing Production Operations	Routine Design	Complex Design Product Development Testing/Evaluation		Basic Research Research/Devel. Theoret. Analysis	
Electrician Factory Assembler Tester Machinist Operator Computer Operator Mechanic		Engineering Aide Service Technician Draftsman Foreman Programmer Inspector	Systems Analysts Technical Sales/Service Project Manager Technical Operations Manager Customer Service Rep. Field Operations Supervisor Data Com. Manager Surveyor		Design Engineer Systems Engineer Product Development Supervisor Plant Manager Engineer			Research Scientist Research Engineer Mathematician Physicists Professor

Figure 1. The Engineering Occupation Spectrum.

profession with a valued channel of new employees. This blurring in the biomedical engineering occupational spectrum provides individuals working in the broad biomedical engineering field having a wide variety of responsibilities, education, professional experience, and job titles as listed in Table 1.

Table 1. Biomedical Engineering Technology Job Categories.[9]

* BMET I: a junior biomedical equipment technician
* BMET II: a biomedical equipment technician
* BMET III: a senior biomedical equipment technician who is not a supervisor
* BMET specialist: a BMET specializing in a particular area, such as radiology or the clinical laboratory
* BMET supervisor: a BMET with group or department supervisory responsibilities
* CE: clinical engineer who is not a supervisor
* CE supervisor: a clinical engineer who supervises a group or department
* Director/manager: the overall group or department director or manager

Bioinstrumentation is the subdiscipline most closely related to BMET and refers to the application of electronics and measurement principles and techniques to develop devices used in diagnosis and treatment of disease. Computers are important in bioinstrumentation, from the microprocessor used to do a variety of small tasks in a single purpose instrument to the extensive computing power needed to process the large amount of information in a medical imaging system.

During the mid to late 1960s, hospitals began significantly increasing their adoption of bioinstrumentation. Public outcries regarding electrical safety of medical instrumentation persuaded the Joint Commission on Accreditation of Hospitals (JCAH) to require hospitals to begin conducting inspections on all new medical equipment along with routine electrical safety testing in 1975.[6] Although many of their duties (equipment inspection, electrical safety testing, and repairs) have remained the same over the decades, some BMETs are entering specialized medical technologies (imaging, clinical lab, sterilization, etc.). The former duties reside in vocational education discipline of the engineering occupational spectrum that generally requires the associate degree while the latter may need more technical or technological training. The former duties are typical in the hospital setting whereas the latter duties are relevant in the independent service organizations (ISO), original equipment manufacturers (OEM), and third-party vendors.

At no time in the history of medicine has the growth in knowledge and technology been so profound.[5] The consequences for those seeking entry into the fastest growing job markets will generally be more than the median level of education.[4] Already the opportunities for employment and the quality of employment are most likely limited for the least skilled and are and will most likely be expanded among the more highly educated. The reward for being technologically literate is strong career fields that typically provide steady employment, training opportunities, fringe benefits, and promotional opportunities.

Strategic Inflection Point

The biomedical engineering field is approaching a *strategic inflection point*[6] (Figure 2), a point in time where extreme forces forever alter the landscape of an industry, creating both opportunities and challenges. The confluence of external forces convening

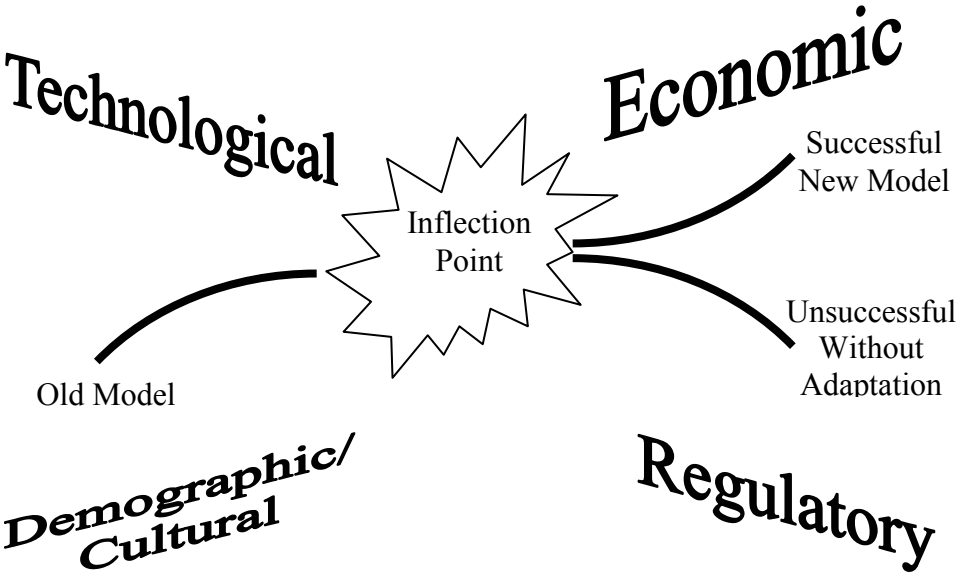

Figure 2. Strategic Inflection Point.

at the inflection point is technological, economic, demographic/cultural, and regulatory forces. In this Dr. Jekyll-Mr. Hyde scenario, ignoring new technologies or unwisely investing in technology creates threats to survival producing a downward spiral into obscurity. Conversely, maintaining an awareness of emerging technologies and the potential for improving productivity and services provides better opportunities of growing and thriving in the future.

As a result of forces described above, health care in the United States will undergo substantial changes within the next 5 to 20 years.[6] Technologically, the challenge for engineering is to devise novel and cost-effective approaches to enable the benefits of new

knowledge to extend to individuals, whether to predict their susceptibility to diseases, to diagnose the nature of diseases or to treat them by genetic means. The ultimate biomedical instrument is the *Star-Trek tricorder* that performs completely noninvasive internal and external measurements, provides imaging, and has the intelligence to make diagnosis and suggest therapy.

Demographically, the health care industry will increasingly focus on the long-term treatment of chronic conditions for an aging patient population. This population will expect high-quality care that is both readily available and reasonably priced.

Economically, the U.S. health care industry is experiencing a financial crisis. Costs are rising faster than the consumer's ability to pay. Biomedical engineering must find a means of reducing costs for the level of health care we are receiving, or if we cannot reduce these costs we must be prepared to adjust our expectations and settle for the level of care we can afford. Technological advances will facilitate the industry's ability to meet these demands and regulatory pressures will foster better integration.

The Future of BMET Education

As a subdiscipline of biomedical engineering, BMET training is also at a strategic inflection point. The pace of the healthcare technology revolution is quickening and tremendous challenges lie ahead for BMET. Ignoring or unwisely investing in the introduction of electronic patient records, complex and extremely powerful electro medical equipment and devices, minimally invasive technologies, new possibilities of providing telemedicine and e-health services, new ways of home self-care, sophisticated new sensors, new ways of care and heath care for older persons provide the threats to the survival of BMET. Conversely, maintaining an

awareness of emerging technologies and the potential for improving productivity and services provides better opportunities of growing and thriving in the future.

Among the threats and opportunities, there is certainly the one related to adequate education of new generations of medical professionals. Presently, BMET training is overwhelmingly provided at the associate level.[10] In 2002, there are approximately 55 programs offering associates degrees in BMET. Smith[11] in 2004 listed two universities with bachelors degrees specifically in BMET (East Tennessee State University and DeVry University) and two universities with bachelors degrees in EET with a focus on BMET (Indianan University-Purdue University at Indianapolis (IUPUI) and New Jersey Institute of Technology). Weber State University in Utah is investigating the possibilities related to offering a BMET oriented bachelors program. DeVry University is a private institution with as many as 15 campuses distributed throughout the U. S. Although not all of the DeVry campuses have a BMET program, many of the campuses are seeking to develop 4-year BMET programs.

For several reasons, this trend will probably change. The regulatory environment (state, institutional, and accrediting agencies) are putting stresses on the BMET curricula. In order to reduce the State's portion of educational costs, the Tennessee Board of Regents (TBR) has mandated that they will fund a 120 semester hour curriculum (128 semester hours for TAC of ABET accredited programs) for 4-year institutions and a 60 semester hour curriculum (64 semester hours for TAC of ABET accredited programs) for 2-year institutions. TBR has also mandated the number of general educations courses required. If all states adopt this philosophy, many of the 2-year colleges will be forced to reduce the number of hours in their technical programs. The Southern Associaton of Colleges and Schools and TAC of ABET places

additional restrictions and requirements on curriculum related to course content. If all states adopt this philosophy, many of the 2-year colleges will be forced to reduce the number of technology hours in their programs.

Culturally, degree inflation has put more emphasis on higher level degrees. That is, a 4-year degree is seen as more culturally distinguishable than a 2-year degree; a graduate degree is seen as more distinguishable than a 4-year degree. One explanation is that at the associate level, BMET has the look and feel of a vocational discipline similar to auto mechanics.[11] By shifting BMET to a 4-year university program, the curriculum becomes perceptibly more valuable and more closely related to the technology side of the engineering spectrum where higher level skills can be taught such as problem solving skills, communication skills, customer service, and dealing with people.

A second explanation why the 4-year degree is more distinguishable is professional growth opportunities. Opportunities for employment and the quality of employment will most likely be expanded among the highly educated. The reward for being technologically literate is strong career fields that typically provide steady employment, training opportunities, fringe benefits, and promotional opportunities.

The associate degree will continue to have a cost advantage when compared with the 4-year degree. In Tennessee, the tuition costs at the 2-year college are approximately one-third the tuition costs at the 4-year university. There will continue to be a place in the technical services area (BMET I, BMET II, and BMET III) of the biomedical engineering occupational spectrum: inspection and testing (functional, safety, performance, etc.), calibration, preventative

maintenance, and corrective maintenance (repair). Some exceptional 2-year graduates will make significant and noteworthy contributions to the field of medical instrumentation.

The bachelor's degree in general provides more opportunities for professional growth through the additional time spent on higher level skills. At East Tennessee State University (ETSU), more time is spent on physics, especially electromagnetism. More time is spent on mathematics, especially the fast Fourier transform that Epstein[12] calls "the Swiss army knife" of mathematical analysis. The BMET program at ETSU has courses on digital signal processing and telecommunications in order to meet the growing demand of processing increasing amounts of data and distributing the data on a shared network. There are a number of courses on personal skills such as technical communications, project scheduling, and supervision. Most importantly, the extra two years in the 4-year BMET curriculum at ETSU allows the student to spend two semesters as an intern at a medical facility.

Some of the graduates of the 4-year programs will compete with graduates of the 2-year programs for the BMET I, BMET II, and BMET III jobs. At ETSU, we expect that most of our graduates will be vying for the BMET specialist, BMET supervisor, and clinical engineering positions. We also expect that some of our graduates will make significant and noteworthy contributions to field of medical instrumentation.

Conclusions

Nowhere are technological advances more apparent than in the healthcare industry where technological innovations have made the practice of medicine more precise and less invasive. Unlike the mature manufacturing sector where computer systems eliminate jobs, the growing and expanding healthcare industry resides in the service sector where computers are creating jobs.

The technological needs of medical instrumentation will require more than the median level of education, and the opportunities fro employment and quality of employment will be more available to the more highly educated.

Clinical information is expanding through expanding technological knowledge. This information expansion will continue as clinicians become globally connected through improved information technology (IT) and telecommunications and information becomes more easily accessible as internet search engines become easier to use. The 2-year limitation of the associate degree provides limitations on the amount of material that can be covered. Although the 4-year limitation of the bachelor's degree provides some problems for the university, the university always has the option of creating graduate courses for those who desire more material.

BMET is at a strategic inflection point. If our choices are not thoughtful, we may find ourselves in a Woody Allen world where:

> We've reached a crucial turning point. One road leads to hopelessness; the other to utter despair. We must have the courage to make the right decision.[4]

BMET can maintain its vocational nature by maintaining its emphasis on inspection and testing, calibration, and preventive and corrective maintenance, or BMET can provide the flow of technologically literate professionals in the more technologically challenging and changing aspects of the medical industry. The natural forces of student desire and employer needs will ultimately provide the solution.

References

1. Nieto, Albert L. *Biomedical Engineering Technology: Analyzing the Professional Marketplace*. J Clin Eng. 2004; 29(1):43-49.
2. U.S. Department of Labor, Bureau of Labor Statistics, Occupational Handbook, 2004-2005 edition. http://www.bls.gov/oco/ocos262.htm (visited 12-27-04), *Biomedical Engineers*.
3. U.S. Department of Labor, Bureau of Labor Statistics, Occupational Handbook, 2004-2005 edition. http://www.bls.gov/oco/ (visited 12-27-04), *Tomorrow Jobs*.
4. Blanton, W. H. Regression Model of the Interactions between Higher Education and High-Tech Industries in East Tennessee and Southwest Virginia. Dissertation. East Tennessee State University. 1992.
5. International Council of Academies of Engineering and Technological Sciences, Inc. (CAETS). *Future Challenges in Biomedical Engineering*. http://www.caets.org/NAE/NAECAETS.nsf/weblinks/NAEW-5CAJK5?OpenDocument#Biomed. (visited 12-27-04).
6. Grimes, S. L. *The Future of Clinical Engineering: The Challenge of Change*. IEEE Engineering in Medicine and Biology. March/April 2003.
7. The Whitaker Foundation. *A Career in Biomedical Engineering*. http://www.whitaker.org/glance/acareer.html. (visited 12-27-04).
8. Grinter, L. E. *Engineering and Engineering Technology Education*. Journal of Engineering Technology. March 1984.
9. Baker *T. Survey of BMET-Training and Clinical Engineering Undergraduate and Graduate Programs in the United States*. J Clin Eng. 2002; 27(3):210-218.
10. Baker T. *BMET Population Ages as Too Few Students Enter the Profession*. J Clin Eng. 2002;27(3):144-148.
11. Smith, R. *The Future of BMET Education*. 24X7. 2004. 9(10):12-19.
12. Epstein, C. L. Introduction to the Mathematics of Medical Imaging. Pearson Prentice-Hall, Upper Saddle River, NJ. 2003.

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