

## **Preparing Freshmen and Sophomores for Biomedical Engineering: The Experience at Northwestern University**

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At Northwestern we believe that we are pioneers in the field of undergraduate education for biomedical engineers. Consequently, we are forever looking for ways to improve what we are doing in both small and large ways. In this paper I intend to describe some of the initiatives we have taken and are taking to open the field of biomedical engineering to underclassmen at Northwestern. I hope that our experience will be useful to colleagues at other institutions. Before I get into the details, however, I feel that I should provide some background about engineering undergraduates and the Biomedical Engineering Department at Northwestern, since what is possible for us may be impractical elsewhere.

Engineering students at Northwestern come from the top five percent of high school students in the U.S., as measured by SAT scores and class rankings. They are highly motivated and have high expectations, anticipating that they will assume leadership roles in their careers and willing to work hard to accomplish this objective. For this reason, among others, we believe that it would be inappropriate to straight-jacket our students with an overly rigid curriculum and we allow them bounded latitude in course selection. We want our students to reach their full potential and not to be limited by a rigid program designed to attain some minimal set of expectations one might have for a B.S. degree in Biomedical Engineering. A number of our students double-major, sometimes with another engineering discipline, but sometimes also with undergraduate programs of Northwestern's College of Arts and Sciences. Occasionally, a student will triple-major. Some of the students who do not double- or triple-major, minor in a discipline from the College of Arts and Sciences. A large fraction of our students gain high proficiency in a foreign language. Some students manage to complete the requirements for both their B.S. and M.S. degrees in Biomedical Engineering in four years, or a little more. Many have exacting extracurricular commitments. Hence, we have a very able student body with which to work, but also one which is very busy.

Among the minimal requirements to graduate with a B.S. in Biomedical Engineering from Northwestern, a student must obtain a strong grounding in mathematics, basic science and engineering and have taken a number of fundamental core courses in biomedical engineering. Students are also required to concentrate a substantial fraction (~20%) of their coursework in one of a number of sub-specialities of biomedical engineering (e.g., biomechanics, biotechnology, instrumentation). In addition to allowing students some freedom of choice, this approach also ensures that the students gain depth in one area, which we believe to be an essential educational objective.

At Northwestern engineering freshmen arrive with undeclared majors. They do not make a preliminary selection of major until the Spring Quarter of the freshman year. Moreover, students can change relatively painlessly between engineering departments through the end of their sophomore year. Biomedical engineering has become a great attraction to today's bright high school graduates with an interest in engineering. It has been the most popular declared interest of incoming engineering freshmen at Northwestern for the past several years. Unfortunately,

most of these students lack a clear understanding of what biomedical engineering is. They have a general feeling that it is something good for society, that biomedical engineers do “neat” things, and that it may be the wave of the future. But, most of them have little or no knowledge of what biomedical engineers do in the real world. Indeed, very few of our prospective student body will have met a biomedical engineer before coming to Northwestern.

There are four challenges, which we face as a department in servicing the large group of underclassmen who might eventually seek training with us. The first challenge is to provide a student, preferably during his or her first year, with a clear picture of what a biomedical engineer is, so that the student can make an informed decision about selecting Biomedical Engineering as a major. The second challenge is to make a student sufficiently aware of the different sub-specialties of biomedical engineering that he or she can intelligently choose an area of concentration. The third challenge is to inform prospective students of the career opportunities available to them if they select biomedical engineering and how a student might shape his or her selection of courses to optimize training for the careers with most appeal. The final challenge is to maintain the morale and enthusiasm of prospective Biomedical Engineering students during the freshman and sophomore years, when they take few classes from the Department.

Like many Biomedical Engineering undergraduate programs around the country we have for many years run a freshman course surveying the field of biomedical engineering. Ours is entitled “Introduction to Biomedical Engineering” (course number 765-A70) and is offered in the Winter Quarter. Of course, the overview of the field of biomedical engineering provided in this course has a Northwestern bias. Many of the Department’s faculty provide guest lectures in which they explain to the students in simple terms an area of biomedical engineering of interest to the faculty member, usually from his or her research field. This approach goes some way to addressing three of the four challenges listed above. It fosters student interest in biomedical engineering during the freshman year. It brings freshmen face-to-face with cutting-edge research in the field and it helps to illuminate the different sub-specialties of biomedical engineering. However, our course fails to give freshmen a clear picture of the possibilities that exist for them as a B.S. graduate in Biomedical Engineering. Neither does it prepare them well for what they will need to do over the next three to four years to optimally prepare themselves for the career possibilities which appeal to them most. In addition, the restructuring of the engineering training of underclassmen at Northwestern that is currently taken place in response to the demands of ABET2000 makes it unlikely that our Introduction to Biomedical Engineering course will be offered in future years.

After pilots which have run for the past three years, in the 1998-99 academic year, all incoming freshmen to Northwestern’s engineering school will enter a four-course sequence in Engineering Analysis which contains linear algebra, differential equations, engineering mechanics, physics mechanics and proficiency in Matlab. This sequence runs from the Fall Quarter of the freshman year to the Fall Quarter of the sophomore year. In parallel with Engineering Analysis, freshmen considering Biomedical Engineering as their major take a three course sequence of calculus, a three course sequence of general chemistry and a two quarter sequence of integrated Engineering Design and Technical Writing. The one remaining course is usually taken in public speaking. For a student without advanced placement credit, there is simply no room for the Introduction to Biomedical Engineering course.

There are three ways that we feel it is possible to meet the challenges listed above within this new environment. One is to ensure that examples of engineering application of the material

covered in the Engineering Analysis courses include those from biomedical engineering. Given the course content, the most natural examples come from the area of biomechanics. The second is to introduce into the Engineering Design course some of the specific design issues that face biomedical engineers (e.g., avoiding the delays introduced by FDA approval, etc.). The third is to exploit extracurricular programs like Northwestern's student chapter of the Biomedical Engineering Society to help enrich our students' awareness of biomedical engineering.

Since our faculty size is small and since we are hard pressed to staff even our upper-level courses, we can only provide a token presence among the engineering faculty teaching the freshman courses. The limited objectives declared in the previous paragraph seem manageable. But, extracurricular activities are also of central importance.

Surveys of our graduates show that a large fraction (~40%) attend medical school immediately after obtaining their B.S. in Biomedical Engineering. Another significant fraction (~25%) go to graduate school, split approximately evenly between those seeking M.S. and those seeking Ph.D. degrees. The other major component (~25%), and it is growing, seek positions in the biomedical industry. The remainder follow diverse career paths (e.g., banking, dentistry, law, military service, optometry, the Peace Corps, veterinary medicine, etc.). Few entering freshmen are aware of this. Many know that medicine is an option. Many trust that there are careers in industry, although most if not all would have difficulty in articulating what functions they would serve there. Less than one would expect consider graduate school a possibility and the other possibilities are simply not imagined.

The Department has therefore supported the student chapter of the Biomedical Engineering Society in its efforts to bring in experts to talk about the field of biomedical engineering and what career opportunities it provides. Some have spoken about what is needed to fulfill the requirements for medical or graduate school or what different sectors of the biomedical industry seek from a B.S. graduate in Biomedical Engineering. There are also talks from different research areas of biomedical engineering and talks on issues such as regulatory practices as they pertain to biomedical products, talks on biomedical ethics, etc. Some of these presentations are delivered by recent graduates of the program, which permits students to gain a realistic impression of what may lie ahead for them.

It is currently unclear what the impact of the disappearance of the Introduction to Biomedical Engineering course will be. How far can extracurricular activities and minor involvement in the Engineering Analysis and Engineering Design courses compensate for its absence? We do not know at this time. However, we are expanding our efforts to disseminate information through extracurricular means, initially through a joint program with the engineering school's Office of Cooperative Education.

The Coop Office perceived that underclassmen who wanted to pursue Biomedical Engineering as a major were at a competitive disadvantage in the hunt for Coop positions because they lacked as clear an understanding of their career potential as say a Chemical Engineer or a Mechanical Engineer. Because most prospective Biomedical Engineers do not know what options are open to them outside of medical school they often appear unimpressive in job interviews. They seem confused about their futures, being unable to say precisely why they want a particular job and what part they expect that job to play in their self-advancement. Furthermore, since these students will have taken little or no course-work in biomedical engineering they have little idea how the job might integrate with their education. Besides the difficulties this poses for the job

hunt process, the poor self-awareness these students have does not mesh well with the objective of a Coop experience. The job and schoolwork should form a smooth marriage, with one component enhancing the other. Consequently, the Department and the Coop Office, in association with Coop employers of Biomedical Engineering students, plan to offer next academic year a series of workshops in which students learn about what lies ahead for them in their years in Biomedical Engineering at Northwestern. Some training will also be provided in interview technique and writing resumés, but the self-awareness aspect is most relevant here. The students who participate in the workshops will be required to hunt through a database of Biomedical Engineering employers. In the process they will gain an appreciation of some of the career opportunities that exist for them. Since our students are very bright and highly motivated they just need some direction at an early stage. Once they gain their bearings, they can explore the field themselves.

For many years there was a big gap between the Introduction to Biomedical Engineering course and the next course taken in the Department by a Biomedical Engineering student, usually a course taken in the Fall Quarter of the junior year. We have for a few years offered three courses that Biomedical Engineering sophomores can take. One is Introduction to Biomedical Fluid Mechanics (765-B70). A second is Introduction to Biostatistics (765-B20) and the third is Introduction to Biomedical Signals and Images (765-C20). In all three of these courses standard material from basic engineering are provided within the context of biomedical applications. These courses are very popular and have both raised morale among our sophomores and helped encourage more potential students to enter the Department.

The Department would like to increase its involvement in teaching during the freshman and sophomore years, but given the constraints of a small faculty size we are currently restricted to follow the plan laid out herein.

**Biographical Information:** JOHN B. TROY is an Associate Professor in the Biomedical Engineering Department at Northwestern University and Associate Chairman of the Department. He has been Chair of the Department's Undergraduate Program for ten years, shepherding it through one ABET cycle. Dr. Troy is a naturalized U.S. citizen, being born in the U.K. in 1951.