

BME Entrepreneurial Literacy

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Summary

Biomedical Engineering (BME) is often seen as the interface between medicine and engineering, but from a practical and societal viewpoint BME lies at the intersection between medicine, engineering, and business. The success of BME will ultimately be judged by the technologies that actually make it to the marketplace to aid in the diagnosis and treatment of disease and contribute to quality of life. Many BME educational programs now offer courses and other opportunities that bring students to the interface of medicine, engineering, and business. This can be called, *BME Entrepreneurship Education*. However, most BME students do not receive this exposure; and it is likely that most students will not have the time, and most university programs will not have the resources, to allocate substantial time and resources towards entrepreneurship education. Nevertheless, there are four concepts, developed in this paper, that can help lower the barriers that prevent wider integration of entrepreneurship into BME programs. The first concept is the notion of *Entrepreneurial Literacy*, that there is a set of core concepts that define an “entry-level” understanding for graduating BMEs. The second concept is the *Entrepreneurial Concept Spectrum*, a set of core concepts in economics, business, marketing and product development that define BME entrepreneurial literacy. The third concept is the *Entrepreneurial Intensity Scale*, a recognition of the diversity of entrepreneurship educational methods and further recognition that these are achieved at different levels of time and resource intensity. Finally, the fourth concept is that of *Teachable Entrepreneurship Moments*, that there are many opportunities in the BME curriculum to connect the subject at hand to the entrepreneurial process, with minimal additional investment of time or resources. These, and other, approaches can provide tools to improve the entrepreneurial literacy of BMEs.

Background

The goal of Biomedical Engineering education is to educate people who will contribute to the improvement of health and quality of life among present and future generations of people. Each graduate of a BME program contributes towards this goal in a different way. BMEs work towards uncovering new knowledge and developing new technologies; but, ultimately, someone has to bring the fruit of this enterprise – medical devices, materials, systems, and services – out of the laboratory and into the marketplace. BMEs, as a group, have both an opportunity and a responsibility to deliver technologies to people; and BME educational programs have both an opportunity and a responsibility to help their graduates fulfill this crucial role.

The kind of education that helps to prepare students for this role can be called *BME entrepreneurship education*. If BME, in general, is thought of as the interface between medicine and engineering, then BME entrepreneurship should be thought of as the triple-point of medicine, engineering, and business. Although the term, *entrepreneurship*, may not be ideal because of its multiple definitions, it nevertheless is probably the best available term to describe the creation of a new business enterprise to introduce a new product or service into the marketplace (with further connotations of *innovation, risk, and rapid change*).¹ Biomedical entrepreneurs are seen as *drivers* of change: people who innovate at the interface of biomedical technology and business, driving both technology and business to achieve better products and services for health.

A Forum on Innovation and Entrepreneurship in Biomedical Engineering Education, sponsored by Stanford University, the National Collegiate Inventors and Innovators Alliance (NCIIA) and The Whitaker Foundation was held in January, 2003, to explore the range of BME entrepreneurship educational programs at 19 different universities. This was followed by another session in September, 2003, where twenty-four additional universities were heard from. Out of these meetings comes a picture of an exciting diversity of educational experiences at the different institutions. There are many examples of product development courses and product-oriented design courses. There are also frequent examples of entrepreneurship courses and projects, sometimes associated with contests and business plans, and sometimes associated with patents and startups. A few institutions have more extensive course offerings and other experiences to allow a student to follow an informal “entrepreneurship track”, or in a growing number of instances, something more formal such as a certificate or degree program.

Nevertheless, in spite of the fact that entrepreneurship education is often accessible to BME students, it doesn't appear to be a standard feature of BME education; and many students graduate without a clear understanding of how BME fits at the intersection of

¹ Although entrepreneurship is typically associated with start-up companies, it is also commonly appreciated that entrepreneurial activities occur within existing companies, leading to new business activities.

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medicine, engineering, and business. Is this a problem? It can be argued that students who are interested in entrepreneurship will choose that route, and students who are not interested will take the “standard” curriculum.

But this argument neglects the fact that we don’t know ahead of time which students will be best situated to become entrepreneurs. We don’t know which students will be serendipitously involved in developing exciting, innovative technologies with great potential for improving health. These students may arrive a point in their careers where they are given the opportunity to bring the fruits of their discoveries to the marketplace, to become entrepreneurs, but are not prepared to do so.

Further, the argument that only interested students need entrepreneurship education – that only entrepreneurs need to know what entrepreneurs do – ignores the reality that entrepreneurs need to build teams, including BMEs, who understand the nature of the entrepreneurial venture. In recent years the majority of new jobs have been created by small to medium size enterprises. Current graduates are highly likely to join entrepreneurial ventures which will depend on their ability to understand the goals and methods of their organization. This leads to the rhetorical question, “How can we expect BME graduates to participate effectively and wisely in a technological society when they don’t fully understand how technology makes its way to consumers?”

Therefore, we are faced with a challenge: to provide more entrepreneurship education to more BME students, within the constraints of BME educational programs. Certainly, it is unlikely that every BME graduate will be fully prepared to become an entrepreneur. But it would be good if some graduated with that trajectory. Conversely, it is not in society’s interest for most graduating BMEs to be unaware of the larger role of BME. This suggests that we first try to outline the kind of knowledge that is most important in entrepreneurship education, and next to identify ways that this knowledge can be made available to the greatest number of students. Below we describe four concepts – BME Entrepreneurial Literacy, the Entrepreneurial Concept Spectrum, the Entrepreneurial Intensity Scale, and Teachable Entrepreneurial Moments – that may help educators in this endeavor.

Concept #1: BME Entrepreneurial Literacy

We define *BME entrepreneurial literacy* as the basic knowledge that allows a BME to *begin* to function at the interface of medicine, engineering, and business. *BME entrepreneurial literacy* implies the most basic concepts necessary for understanding, but not all those required to actually launch, an entrepreneurial venture. This level of knowledge is critical and should be part of every BME program, hence the use of the label *literacy*.

The core of entrepreneurial literacy is a basic knowledge of business structures and processes, along with an understanding of the importance of market and customer needs. However, while these may suffice in other engineering fields, BME entrepreneurial literacy also includes appreciation for the unique features of the medical device, pharmaceutical, and medical service industries. Most importantly, literacy includes some

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notion of how the supply and demand for medical technology is influenced by government funding of healthcare services, government regulation of medical technology, patterns of healthcare practice, and disease demographics.

Concept #2: The Entrepreneurial Concept Spectrum

One way of viewing the components of BME entrepreneurial literacy is according to a *entrepreneurial concept spectrum*, moving from basic economic concepts, to basic business concepts, and finally to product development concepts. This structuring highlights the truth that the development of biomedical products and services takes place within a business context, which in turn, takes place within a larger economic context.

NOTE: WE NEED A SNAPPIER TABLE THAT SHOWS THE RANGE MORE CLEARLY

Concept Spectrum for BME Entrepreneurial Literacy		
← Entrepreneurial Literacy Concept Spectrum →	← Economic	The Market -- Supply & Demand
		Government Effects
	← Business	Investment and Finance
		Business Structures
	Product	Market characteristics: Healthcare Practice & Health Demographics
		Regulatory considerations
		Understanding customer needs

Concept #3: The Entrepreneurial Intensity Scale

The challenge for achieving entrepreneurial literacy, both for students and faculty, is how to fit it into a crowded BME curriculum. Rather than attempting to devise a “one size fits all” approach, it might be more useful to discuss two ideas that suggest methods for enhancing entrepreneurial literacy components in the curriculum. These ideas do not necessarily guarantee that *every* BME student will achieve entrepreneurial literacy at the highest level, but nevertheless can help to increase the overall entrepreneurial literacy of BME graduates. The two ideas are: 1) the *Entrepreneurial Intensity Scale*; and 2) the use of *Teachable Entrepreneurial Moments*². These are discussed in the next two sections.

The *Entrepreneurial Intensity Scale*, shown below, is a representation of the range of learning intensities through which elements of entrepreneurial literacy can be offered. At the high end, there are E-Team Projects² and entire courses devoted to business subjects; at the low end, there are individual readings, lectures, and case studies that touch on economic, business, or product development concepts. In the middle there are opportunities to expand upon economic, business, or product development concepts in senior design projects and other kinds of research projects.

Entrepreneurial Intensity Scale	
Low Intensity ↑ ↓ High Intensity	Readings, including Case Studies
	Lectures, including Case Studies
	Group Exercises
	Assigned Research Projects
	Independent Research Projects
	Design Project
	Design Project with Product Development Focus
	Industrial Internship in start-up environment
	Entrepreneurial-Team (E-Team), Early stage
	E-Team, Advanced

² E-Teams are multidisciplinary self directed design and development projects with a commercial focus..

Concept #4: “Teachable Entrepreneurial Moments”

Educators are very familiar with the concept of “teachable moments”, opportunities that allow the teacher to connect the narrow subject-at-hand to the larger world (or the reverse, to connect the larger world, to the narrower confines of the classroom). This approach provides a very low intensity, and very natural, technique to enable BME entrepreneurial literacy. *Teachable Entrepreneurial Moments* are points in lectures, discussions, or projects that can be connected naturally to BME economic, business, or product development concepts. Teachable moments abound in the BME curriculum. It is only a matter of asking students leading questions and saying, “Why don’t you look up ...”, or saying, “If this were a medical product ...” The purpose of these teachable moments is to reorient the students to a larger world. Listed below are some situations where teachable moments can be applied.

Teachable Entrepreneurial Moments in BME Lecture Courses	
When teaching a concept or phenomenon,	Point out the device or disease related to that concept or phenomenon.
When mentioning a disease or medical condition,	Ask the students to find out: <ul style="list-style-type: none"> • How many people have that disease and how they access treatments • What technologies are used to diagnose and treat the condition • How much the disease costs in both monetary and human terms
When mentioning a medical device or technology,	Ask the students to find out: <ul style="list-style-type: none"> • what diseases the device relates to • how many people benefit from the technology • what the costs of providing treatment with this technology are and how these costs are paid • whether there are other technologies that do similar things

Teachable Entrepreneurial Moments in BME Design Courses
Ask the students whether there is anyone else, besides their advisor/client, who would use the design that they are developing.
Ask the students whether their design has commercial potential and how they would know.
Ask the students how large their market might be.
Ask the students to identify competing products, services, and technologies.
Ask the students whether there is some way they could modify or extend their design to reach a larger market.
Ask the students whether the technology and concepts employed in their design have applications outside of their narrow focus.

Discussion

These concepts about entrepreneurial literacy were presented at a third meeting of the Biomedical Engineering Innovation Design, and Entrepreneurship Alliance (BME-IDEA) in October, 2004. In attendance were participants from 47 universities, three biomedical device companies, and four foundations supporting design and entrepreneurship programs in universities. The meeting included a special workshop session devoted to the question of entrepreneurial literacy in BME, along with follow-up discussion in the general meeting. From these discussions emerged a consensus view that entrepreneurial literacy was not only a recognizable attribute in students, but also an achievable educational goal. The “entrepreneurially literate” student was deemed one who had the “ability to have a conversation” about medical technology with a group of people that included doctors, engineers, and business people. A persistent, and repeated, point made by many meeting participants was that the most fundamental *skills* required for entrepreneurial literacy are, in fact, communication skills – the ability to communicate to both technical and non-technical audiences. This view is consistent with the notion of “literacy as the ability to have a conversation”. Another important component of entrepreneurial literacy that frequently emerged during discussions was a “mindset” towards recognizing opportunities and possibilities. This mindset is best described – not only as the ability to see connections between medicine, engineering, and business – but also as a restless *searching* for connections between medicine, engineering, and business.

Perhaps the most interesting question to be taken up in discussion was whether entrepreneurial literacy is, practically speaking, achievable in the typical BME undergraduate program. The consensus view was that it is achievable, and at minimal “cost”, through a three-pronged approach involving: 1) the BME senior (or capstone)

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design course; 2) a second product-development, entrepreneurship, or technology-focused course that specifically sets out to make the connections between medicine, engineering, and business; and 3) an extracurricular environment that exposes students to a wider view of BME and its possibilities. All accredited BME programs already have item 1, the design course. In addition many programs now have a product-development course (item 2), or something similar, taught within the department or available elsewhere in the university. Item 3, the extracurricular environment, however, was identified as an area that was underdeveloped, or underappreciated, at many institutions. Examples of extracurricular opportunities include guest lectures from people who have started biomedical companies and/or have invented medical devices, and from recent BME graduates working in industry. Another example is a business-plan competition. What seems most important is for students: to learn about BME activities outside of their restricted local environment; and to actually hear a fluent conversation – involving medicine, engineering, and business – about biomedical technology. That is, students acquire BME entrepreneurial *literacy* by being exposed to people who have acquired BME entrepreneurial *fluency*.

Conclusion

Modern biomedical engineering educational programs are based upon the premise that the future of healthcare depends upon educating people at the interface of medicine and engineering. Perhaps this premise is not quite large enough. Maybe the future really depends upon educating people at the interface of medicine, engineering, and business. Medicine gives rise to the need for new technologies; engineering provides the means for these new technologies; but business provides the vehicle for delivering the technologies. Let us call the people who will *lead* at this triple interface, *BME entrepreneurs* – and the education necessary to *participate* at this interface, *BME entrepreneurial literacy*. The pioneers in BME education found ways to integrate engineering education with medicine and biology. New pioneers are needed to find ways of integrating current BME education with a greater world that includes economics, business, and product development.