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Manpower Development for the Biomedical Industry Space

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Abstract —**The Biomedical Sciences (BMS) Cluster is one of four key pillars of the Singapore economy. The Singapore Government has injected research funding for basic and translational research to attract companies to carry out their commercial R&D activities. To further intensify the R&D efforts, the National Research Foundation (NRF) was set up to coordinate the research activities of different agencies within the larger national framework and to fund strategic R&D initiatives. In recent years, funding agencies began to focus on support of translational and clinical research, particularly those with potential for commercialization. Translational research is beginning to have traction, in particular research funding for the development of innovation medical devices. Therefore, the Biomedical Sciences sector is projected to grow which means that there is a need to invest in human capital development to achieve sustainable growth. In support of this, education and training programs to strengthen the manpower capabilities for the Biomedical Sciences industry have been developed. In recent years, undergraduate and graduate degree courses in biomedical engineering/bioengineering have been developing at a rapid rate. The goal is to train students with skills to understand complex issues of biomedicine and to develop and implement of advanced technological applications to these problems. There are a variety of career opportunities open to graduates in biomedical engineering, however regardless of the type of career choices, students must not only focus on achieving good grades. They have to develop their marketability to employers through internships, overseas exchange programs, and involvement in leadership-type activities. Furthermore, curriculum has to be developed with biomedical innovation in mind and ensure relevance to the industry. The objective of this paper is to present the NUS Bioengineering undergraduate program in relation to manpower development for the biomedical industry in Singapore.**

Keywords: Bioengineering Education, Undergraduate Study, Enhancement Programs

Background

At the turn of this millennium, the Singapore Government announced the development of a Biomedical Sciences (BMS) Cluster as one of four key pillars of the Singapore economy [1]. The cluster included the pharmaceuticals, medical device technology, biotechnology and healthcare services. This BMS initiative is spearheaded by the Singapore's Economic Development Board's (EDB) BMS group; its investment arm, Bio*One Capital; and the Agency for Science, Technology and Research's (A*STAR) Biomedical Research Council (BMRC) and Science & Engineering Research Council (SERC). These organizations were charged with developing Singapore's industrial, intellectual and human capital to support the BMS initiative. In tandem with infrastructural development, the Singapore Government injected research funding for basic and translational research to attract world class companies to carry out their commercial R&D activities in Singapore. To further intensify the R&D efforts, the Singapore Government established the National Research Foundation (NRF) on 1 January 2006 to coordinate the research activities of different agencies within the larger national framework and to fund strategic R&D initiatives. The three areas of research focus are Biomedical Sciences, Environmental and Water Technologies and Interactive and Digital Media. In 2006, the Singapore's Ministry of Health set a mandate to support translational and clinical research. Consequently the National Medical Research Council also began funding research projects that has potential for commercialization. Translational research is beginning to have traction, in particular research funding for the development of innovation medical devices.

With the projected growth in Biomedical Sciences sector, investment in human capital development becomes crucial for achieving sustainable growth. In support of this, education and training programs to strengthen the manpower capabilities for the Biomedical Sciences industry have been developed.

In view of this, universities across the world have established new departments to offer new undergraduate and graduate degree courses in biomedical engineering. Most of these courses focus on the study of micro/nano-bioengineering at the molecular and cellular levels; biomaterials and tissue engineering; biomechanics and computational bioengineering; bioinstrumentation; and biomedical imaging. The goal is to train students with skills to the understanding complex issues of biomedicine and to develop and implement of advanced technological applications to these problems. However, equally important is that it should also provide an education to make them relevant and marketable for the BME industry. Therefore while principles and concepts in BME are important foundation knowledge we try to impart, we also hope that students acquire adaptive expertise such that they can be continuously relevant in this dynamic field.

NUS Bioengineering Program

The bioengineering program at the National University of Singapore started in 2002. It is 4-year accredited Bachelor of Engineering (Bioengineering) degree. The student intake has steadily increased over the years, the first intake in 2002 was

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42 and the intake last year, ie 2012 was 95. So far we have had 7 batches, totaling 428 students that had graduated.

The aim of this program is to produce engineers with strong foundation in relevant engineering and biosciences disciplines to contribute to the biomedicine through innovation, enterprise and leadership. The characteristic of the educational program is to provide a strong emphasis on scientific and engineering fundamentals and a high degree of flexibility which can provide a wide diversity of educational experiences. It strives to graduate versatile engineers who would be best positioned to lead and be an integral part of the biomedical engineering industry. The undergraduate core subjects are representative of the diverse nature of bioengineering, with a pool of modules allowing students the freedom to select modules from their area of interest and their intended specialization. There are four concentrations or specializations:

- Biomaterials and Tissue Engineering
- Bioimaging and Biosignal Processing
- Biomechanics and Computational Bioengineering
- Micro/Nano- Bioengineering

In a recent survey done for the Engineering Accreditation Board, our "Student Learning Outcome" achievement measure was on average 76%. The content and learning outcomes would generally satisfy the variety of career opportunities open to graduates in biomedical engineering. They may pursue a career in universities or research institutes, biomedical businesses, hospitals, and government agencies. Others would use the biomedical engineering or bioengineering degree as a pre-med option for graduate medical studies, while others would start up company to develop the medical devices they had worked on in their final year projects. In our recent survey of our alumni, 30% stated that they are enrolled in postgraduate studies (either MSc, PhD or MD) and 55% are employed in healthcare-related companies with job scopes ranging from product design, regulatory affairs to patent attorney.

Regardless of the type of career choices students will finally choose, it is imperative that students must not only focus on achieving good grades. They have to develop their marketability to employers through internships, overseas exchange programs, and involvement in leadership-type activities. In view of this we have developed the following enhancement programs:

Design-Centric Program (DCP)
The unique feature of the faculty-wide Design-Centric Program (DCP) is that students spend 3 to 3.5 years working together on multi-disciplinary projects addressing complex and coupled problems in teams composed of students from different engineering disciplines. Teams of mentors from diverse backgrounds are available to guide these students. There is also the element of "generational learning" and opportunity to attend Design Summer Program and DCP Residential Program.

Vacation Internship Program (VIP)
Students participate in this internship either through placements or by sourcing for companies on their own. The internship must have substantial engineering content (incl. technical skills) and in addition, students would have to be exposed to some, if not all, of the following:

- Management
- Computer applications
- Cost implications
- Safety measures
- Quality control
- Marketing
- Customer Service

Student Exchange Program (SEP)
The Student Exchange Program (SEP) allows students to spend a semester or two at an overseas partner University, earning credits towards their NUS degree. The list of overseas partners includes top universities from over 40 countries around the world. SEP is a chance for students to experience student life in a foreign country and learn to be a global citizen. It provides an opportunity for students to pick up a new language, absorb new cultures and make new friends.

NUS Overseas Colleges (NOC)
There are 7 NUS Overseas Colleges around the world; in Silicon Valley and Philadelphia, USA; Beijing and Shanghai, China; Stockholm, Sweden; India and Israel. These colleges are established in leading entrepreneurial hubs. The program targets students with the academic ability and entrepreneurial drive, keen to be immersed as interns in start-ups located in leading entrepreneurial and academic hubs of the world. At the same time, they will study entrepreneurship related courses at highly prestigious partner universities. The aim is to cultivate and nurture them into enterprising, resourceful, independent self-starters and eventually blossom into successful entrepreneurs.

Joint Summer School Program
This 3-week program is jointly organized between the NUS Department of Bioengineering and the Department of Biomedical Engineering, Zhejiang University (ZJU), Hangzhou, China. This undergraduate Special Term Study Abroad Program is a 4-credit module on Principles in Bioengineering will be taught at Zhejiang University over this 3-week period during the Special Term. Approximately, 15 students from NUS join another 15 students from ZJU usually enroll in this program. This program provides opportunity for cross-cultural interaction, using problem-based learning to allow students to learn from each other in the area of teamwork and leadership. This helps to establish networking contacts among the students.

Exposure/Exploratory Field Trips
The NUS Department of Bioengineering organizes field trips to partner universities in South Korea, Hong Kong and Thailand. These trips are normally 2-week in duration. Apart from visits to BME departments and BME-related industries, the students are also exposed to cross-cultural and social interactions.

These various enhancement programs made available to students provide cross-cultural and cross-discipline learning experiences, nurturing teamwork, developing leadership skills as well as cultivating that factor which adds value to your personality, otherwise known as the "X-Factor".

Emphasis in Design

Another key element which we have added to our program is an emphasis on design. Our approach is to present the design challenge in a problem-focused modular format to enable the student to acquire new skills to solve a real world bioengineering problem drawing upon relevant knowledge acquired from other courses. The intent is to create a real world experience by introducing real world medical problems requiring design solutions. Students are introduced to concepts, processes and frameworks for analyzing user needs, creating and documenting design solutions and defining and identifying constraints.

Design training is introduced at every level of program. At the freshmen level, the main objective is to give an introduction to bio-inspired design so as to gain an understanding of how biomimetic principles can be used to address engineering problems. Students will discover how one can mimic nature/biology to provide solutions to bioengineering problems. In Year 2, students are given the scenario that they are working in a Medical Device company and that they do not have a choice in deciding who their team members are. They are then given a small budget and a deadline to do a proof of concept design. The design team builds on the "paper" design which the students have done in a previous module and then present to the "management" for evaluation. In Year 3, the emphasis will be placed on providing bioengineering design solutions within the constraints of regulatory requirements, economics and bioethical issues while at the same time appreciating the clinical environment and clinical needs in which the design solution will have to operate in. The students will be assessed on teamwork, project-based learning and entrepreneurial thinking. The team-based term projects will require design process documentations and oral presentations. This module aims at providing the basic tools and skill sets to enable the students to develop solutions for real world medical problems. Each of the team members take on the following different roles:

- Design methodology
- Quality systems
- Intellectual property protection
- Design validation
- Regulatory requirements
- Ethical Issues
- Marketing
- Costing

In the final year, students will have to undertake a two-semester long individual-based project. This is to provide an opportunity for the student to develop independence in planning and completing a research project. We conduct a pre-project commencement class on Research Methodology; Ethics in BME research and Laboratory Safety to prepare the students. Upon completion, the students will have to submit a thesis for examination and make an oral presentation through a poster. The Department concurrent organizes the "Bioengineering Showcase" event where graduating students will be given a chance to present their work to representatives from industry. This event offers a recruitment opportunity as well as networking with the industry.

Academia versus Industry

While most BME programs hope to produce graduates that would be industry-ready, it is interesting to note that there are differing perspectives between academic education and industry's need which may result in differing placement of efforts and resources. For instance, in the approach to translational research; design of device and therapy format ranks high in academia while for the industry, the priority is to achieve success in Phase III clinical trial. Therefore, quality management system as well as risk assessment and management are of prime importance to the industry. However, current BME programs are already packed with engineering and life sciences courses. The challenge then is to achieve a balanced perspective in BME education. In order to achieve this, we have convened a departmental consultative committee made up of representatives from various biomedical-related companies. The role is to provide feedback on the relevance of our curriculum and to make recommendations for improvement. We have found that the committee has been an invaluable part of the strategic progress of the department, offering timely feedbacks and creating that balanced perspective.

We have established the Bioengineering Industry Alliance (BIA) as a platform, bridging companies' needs and interest with our staff and students. BME-related companies are invited to join, contribute and benefit from the BIA. The goal is to form strong links between the industries and our faculty and students. We welcome companies, startups, government bodies and related organizations as members. BIA members will have opportunity to interact with our faculty and students through networking sessions, expose to cutting edge research and advanced facilities, develop research collaborations and propose research projects, and participate in our seminars and workshops, so as to provide value to your organization. We invite BIA members to propose and fund industry-relevant projects. There exit possibility of students working on these projects on the premise of the companies. We hope that this will motivate and introduce students to real world problems as well as to facilitate recruitment opportunities for the companies.

BME Career Decision: A Demand-Supply Paradigm

While the academic institutions in collaboration with industry are able and capable of producing the demand and supply of BME personnel, nevertheless the situation is dependent on government policies, industrial activity, technology advancement, industry awareness and public awareness. Fortunately the current BME career seems to enjoy high growth potential, this could be due in part to the aging baby-boom generation which is expected to increase demand for biomedical devices and procedures and the increased awareness and desire to maintain healthy and active lifestyle [2].

Singapore's Medical Technology Innovation Push [1]
In 2011, Singapore's medical technology sector contributed about S$4.3 billion in output and about 9,000 new jobs. There is a trend towards increased Medical Technology (Medtech) innovation in Asia. In view of this, 30 Medtech companies now carry out R&D in areas such as value engineering and product development for regional and global markets from Singapore. They include Becton Dickinson, Biosensors, Hill-Rom, Siemens Medical Instruments, Menicon, Thermo Fisher, Welch Allyn, AB Sciex, Vela Diagnostics, Qiagen, as well as local start-ups like HealthSTATS and Veredus Laboratories.

Inevitably, the kind of BME graduates we hope to produce that would be relevant for this growing segment will have to be versatile to deal with technical, marketing and management jobs. Therefore, flexibility of program that offers students choice of career paths, including minors and double degrees in business, technology management and accounting etc, would be very useful. As evident from our cohorts of alumni, the variety of jobs BME graduates hold includes R&D, Quality & Regulatory, Managerial and Sales/Marketing etc.

However, even with the upward trajectory of Med Tech industry, BME graduates still face some employment challenges. They as follows:

- There are people from industries that are still unaware of the discipline of biomedical engineering or bioengineering
- There is a misconception or misperception that BMEs are less of an engineer and not as well-trained
- There are those in the industries who are still unaware of the education and training involved in the BME curriculum

Therefore, university career centers need to make efforts to educate the industry on the capability of BME graduates. Department needs to showcase their BME students' skill sets, in particular demonstrate the students ability to work in a team, having qualities of adaptability, communication and compassion. BME graduates have to improve their marketability. In this vein, Wnek and Williamson (2010) [3] made a poignant remark in their article "Engineering Value Propositions: Professional and Personal Needs". They said and I quote: "First and foremost, engineers contribute to value creation with deep analytical thinking grounded in scientific principles. But successful innovation requires consideration of a broad set of issues (e.g., markets, customers, intellectual property protection, financing, sustainability) and a broad set of skills (e.g., communication, teamwork, project management, and the ability to spot emerging opportunities)."

Concluding remarks

Manpower development for the biomedical industry is a multi-faceted endeavor, not only is there a need to train competent biomedical engineers but also to cultivate and nurture teamwork and leadership. BMEs play an extremely important role as it interfaces between the medical community and product manufacturers to improvement healthcare and medical practice. After all, the prime goal of biomedical engineering is to improve healthcare and wellness.

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