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Teaching Bioprocess Technology to Non-Engineering Students of Chemical and Biotechnology in Hong Kong

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1. Introduction of bioengineering

Concerning about the field of biotechnology, there are so many terms used to describe its branches. *Bioengineering* is a broad title and mainly implies the application of engineering principles to biology and medicine. In industry, bioengineering is regarded as a high-tech enterprise providing mainly health care products and services. *Biological engineering* is similar but emphasizes application to plant and animals. *Bioprocess engineering* refers the application of mechanical, electrical, and industrial principles to process based on using living cells or its subcomponents. *Biochemical engineering* has usually meant the extension of chemical engineering principles to systems using a biological catalyst to bring about desired chemical transformations, which is subdivided into bioreaction engineering and bioseparations. *Biomedical engineering* has been considered to be totally separate from biochemical engineering, though the boundary between the two is increasing vague, especially in the area of cell surface receptors and animal cell culture (Shuler and Kargi, 2002).

Bioengineering has been one of the most rapidly advancing fields of engineering in the past 3-4 decades and will remain a hot field of engineering in the 21st century. Bioengineering is a multidisciplinary major based on physical, biological and chemical sciences, encompassing bioprocess engineering (production), biomedical engineering (design of materials and devices), and perhaps also agricultural engineering, connected with mechanical, electronic and manufacturing engineering.

2. Background and features of Hong Kong and its engineering education

Hong Kong has become a financial, tourist, transportation and manufacturing service center and an entrepot in the Pacific-Rim, since the successful implementation of the "open door" policy in China Mainland and its manufacture industry moving mainly into the Pearl River Delta. In these years, Hong Kong has been facing keen competition from its neighboring countries and region in both manufacturing and financial services. In order to maintain its leading position, Hong Kong should emphasize innovation in all

economic sectors, in term of introducing improved technology and methods, penetrating new market segments, and entering into activities of higher value. This is a challenge that the tertiary education sector should take on board and react positively, particularly the engineering education, which contributes towards greater economic growth and better living standard. However, Hong Kong has a service-oriented economy with very small process and manufacturing industry, providing rarely any jobs in industrial process or engineering. At the same time, there is a general trend of young people preferring to study finance and management course in recent years, and it will be important to attract some good students to study engineering programs. Therefore, engineering education has to be changed and refined so that the graduates can contribute towards the development and provision of high-value-added products and services. Now, about 2,500 undergraduates (nearly 20% of total freshmen) join engineering degree programs in one of the six renowned universities in Hong Kong every year.

3. Challenge of bioengineering education in universities

Biotechnology-related industries do not have a long history in Hong Kong. In the past century, only the food and beverage industries and some pharmaceutical or Traditional Chinese Medicine industries were operational. As a financial and manufacturing service centre, Hong Kong has a strong potential to develop biotechnology. With an excellent information network, well-trained personnel and state-of-the-art equipment, Hong Kong has become a regional hub for the biotechnology industry in the past 20 years and attracts international biotechnology companies to set their eyes on the vast market opportunities available in the neighboring China Mainland (Tsang et al., 1996). The academic institutions in Hong Kong have been playing their roles by developing undergraduate and post-graduate degree courses in the relevant area.

Bioengineering addresses scientific and technological questions across the full breadth of scales in biology: molecular, cellular, tissue, organism, and systems. The educational programs in the bioengineering division reflect this emphasis on science and engineering approaches to biological problems, with opportunities for graduate in either bioprocess or biomedical engineering. Bioengineering programs or courses are offered in most Hong Kong's universities of science and technology including our own.

Nevertheless, the biotechnology and chemical technology programs in our department are mainly to train technologists but not engineers. After graduation, most students work in testing and analytical labs, chemical products formulation factories, technical sale and marketing, even business not relevant to their majors in university. At the same time, Hong Kong is a dynamic and rapidly changing society, which requires the workers to learn new knowledge and skills continuously to adapt to new jobs. In addition, the students prefer finance more than engineering, and generally they show few interests in physics or mathematics.

Hence, here lie the dilemma and the challenges, that is:
The Scope: What has evolved as the domains of bioengineering and what is the most promising direction? What should we do to connect with various other disciplines?
The Skills: What and how should bioengineering be taught? How should we, as teachers or scholars, upgrade and sustain ourselves with professional skills?
The Prospects: What is the job market for bioengineering graduates at all levels? What is the philosophy and infrastructure that would sustain the field?

4. Introduction of bioengineering education in Hong Kong's universities

In order to give the graduates a promising career, they must be trained to satisfy the requirements and favors of the society and industry. Therefore, grasping the essential knowledge in undergraduate study is a tough challenge to the students, and the main features of these programs should be application-oriented (applied sciences) and broad-based (rather than specialized or advanced) to fit the background of students and their future job needs. At the undergraduate level, the bioengineering curriculum should emphasize the fundamental and general aspects (as the core) of bioengineering science and technology, and offer the more specialized and advanced subjects of bioengineering as electives for senior students or for postgraduates. The curriculum should also encompass the foundation courses including physics, mathematics, biology, and chemistry at the junior level. At the advanced levels (senior undergraduate of postgraduate), the program should be divided into different majors, such as processing/manufacturing engineering (biochemicals and pharmaceuticals) and biomedical engineering (materials and devices).

4.1 Bioprocess engineering Program

4.1.1 Introduction

A bioprocess engineer applies knowledge and techniques from different engineering fields like thermodynamics, process control and biotechnology. He/she also utilizes information from chemical, material and biological sciences and economics to develop and commercialize new products and processes efficiently. The continuing growth of health-care and bio-related industries has resulted in an increasing demand of biochemical engineers specialized in biology/biomaterials and life-sciences. To anticipate this growing need, the Department of Chemical Engineering at the Hong Kong University of Science and Technology has established a new undergraduate program: Chemical & Bioproduct Engineering from the academic year of 2004/05. This program is the first of its kind among all the Universities in Hong Kong.

4.1.2 Program characteristics and highlights

The bioproduct program incorporates a unique combination of new approaches adapted from biology, biochemistry, cell biology and pharmaceutical engineering with fundamental concepts from chemical engineering. Students will be trained to understand the basic principles of life and pharmaceutical sciences and apply engineering knowledge to process design, manufacture bioproducts and biodevices.

4.1.3 Core Course

Cell Biology, Nature of Biochemistry and Biotechnology, Chemical Process Principles, Products and Processes, Chemical Engineering Thermodynamics, Process Design and Integration, Reaction and Reactor Engineering, Separation Processes, Process Fluid Mechanics, Heat and Mass Transfer, Bioproduct Engineering Laboratory, Chemical Engineering Laboratory, Process Dynamics and Control, Plant Design and Economics, Bioproducts and Processing, Biomolecular Engineering, Process Design Simulation, Chemical and Bioproduct Engineering Project, Physical Chemistry: Fundamentals and Applications, Engineers in Society, Calculus, Multivariable Differential and Integral Calculus, Introduction to Linear Algebra, Introduction to Ordinary Differential Equations, Introduction to Numerical Methods

Elective Courses

Industrial Training, Computer and Programming Fundamentals, Engineering Management, Business and Management, Humanities and Social Science, English for Engineering Students, Academic and Professional Development, Healthy Life Style

4.1.4 Career Prospects

The graduates in Chemical & Bioproduct Engineering will be prepared for a career as:

1. Biochemical or Bioprocess Engineer: designing a process for antibiotic or drug production in the pharmaceutical industry, or carrying out process improvements to achieve higher productivity and quality in the food and beverages industry;
2. Quality Engineer: ensuring product quality in a brewery plant by using different analytical instruments in the beverage industry, or controlling food safety and water quality in a government laboratory or agencies;
3. Pharmaceutical Engineer: making life-saving medicines from herbs or Traditional Chinese Medicines in the corresponding industries;
4. Sales or Marketing Engineer: providing world class bioproducts, equipments and technical services to consumers, manufacturers, laboratories and universities;
5. Research Engineer, developing diagnostic chips, drugs or cell culture methods at a research center of the biotechnology industry.
6. Providing technical service in industries or as consultant for safety, finance and insurance.

4.2 Biomedical engineering program

4.2.1 Introduction

Biomedical engineering is recognized as one of the fastest growing areas of innovation, which is on a spectacular development fast track around the world. It encompasses both engineering principles and human life science with the aims of advancing and developing knowledge in bioinstrumentation, biomaterials, medical devices and bioinformatics for the prevention, diagnosis and treatment of disease, for patient rehabilitation and for improving health. Examples include sensors and instrumentation systems that are used by health professionals for their diagnostic, therapeutic and

rehabilitative practices; implants that are placed in patients for their health maintenance; prostheses, orthoses and assistive devices that are used by people with special needs to facilitate their daily activities. This global development requires professionals who understand both the health issues that motivate these technologies and the engineering solutions that they offer. The developing field needs individuals with a solid foundation in both health sciences and engineering technology. As the geriatric population in Hong Kong and around the world increase steadily in the coming decades, there will be a high demand for biomedical engineers. On another front, biotechnology is defined as the application of scientific engineering principles regarding the use of living organisms to improve the quality of life of all mankind. In this post-genomic era, a significant portion of the genetic information collected from various model organisms including humans in the biopharmaceutical context has yet to be used. There will be a high demand for biotechnologists who can help to decipher this enormous pool of information.

The BSc Program of Biomedical Engineering in the Department of Health Technology and Informatics (the Hong Kong Polytechnic University) announced its official inauguration in Septemper 2005. This program will bring the students opportunities to take subjects in both life sciences and engineering, and to integrate these concepts in interdisciplinary applications to improve human health.

4.2.2 Program characteristics and highlights:

Biomedical engineering is a discipline that advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate engineering sciences with biomedical sciences and clinical practice. By combining biology and medicine with engineering, biomedical engineers develop devices and procedures that solve medical and health-related problems. This program also equips students with interdisciplinary expertise in both biomedical engineering and biotechnology to meet the growing demand both locally and internationally. The unique combination of these two disciplines will enable graduates to apply engineering principles and biopharmaceutical techniques competently in understanding life phenomena and in solving relevant problems in healthcare and related industries.

4.2.3 Core courses

Human Physiology, Applied Mathematics, Computer Programming, Generic Anatomy, Introduction to Biomechanics, Introduction to Health Technology, Professional English for Biomedical Engineering, Computer Programming, Bioelectrical Technology I: Circuits & Systems, Bioelectrical Technology II: Electronics, Principles of Human Movement Analysis, Mechanics of Tissues and Biomaterials, Material Processing, Computational Methods, Orthopaedics, Trauma & Rehab, Medical Science, Principles of Bioinstrumentation, Biosignal and Image Processing, Methods of Investigation & Proposal Writing, Biomedical Engineering Laboratories, Holistic Health Care, Electrophysiological Instructure & Measurements, Biomedical Engineering Design, Introduction to Transport Process in Living Systems

Elective course:

Biomaterials and Biotechnology Subjects:

Biomaterials Science and Engineering, Biomaterials and Tissue Engineering, Cell Biology, Introduction to Biotechnology, General Chemistry, Biochemistry, Genetics, Biochemical Techniques, Chemical and Bioprocessing Technology

Other Engineering Related Subjects:

Economics for Engineers, Computer System Fundamentals, Data Structures and Databases, Interface and Embedded Systems, Data and Computer Communications, Cost Effectiveness of Health Technology, Intellectual Property, Standards and Regulation of Medical Devices

Besides building upon the foundation knowledge through classes on campus, students will go through 420 hours of action learning through industrial and clinical attachments. These attachments offer a good opportunity for students to put what they have learned into practice.

4.2.4 Career Prospects:

Graduates of this program can take up their careers from such fields,

1. Be prepared for professional opportunities in biomedical engineering, orthotics, prosthetics and other health technology related fields;

2. Be able to work as biotechnologists or as engineers who can apply advanced biological techniques in solving clinical and related industrial problems.
3. Take up careers in the development, design, manufacture, distribution and/or use of biomedical equipment and technologies in different industrial and clinical contexts.
4. Become part of a rehabilitation team to provide holistic and integrated clinical services in the public or private sectors.

5. Share of personal experiences in teaching bioprocess technology

Concerning of the students' weak mathematics and few interests in engineering, and the requirements of society and industry, the main features of our programs should be application-oriented (applied sciences) and broad-based (rather than specialized or advanced) to fit the background of students and their future job needs.

To be effective, instruction should be knowledge centered, student centered, assessment centered and community centered (Harris and Brophy, 2005).

Give examples to demonstrate the personal experiences in teaching bioprocess technology in the university, including difficulties in teaching and student learning, and the approaches to overcome these problems and the outcomes (both failure and success)...

6. The tomorrow of bioengineering education

The 40 year history of bioengineering as an area of research and an academic subject suggested that a significant body of facts, theories, methods, skills and integrative reasoning regarding bioengineering was in existence. However, systematic study to determine the most important subsets of knowledge for various levels of students and the best methods for teaching it are still needed.

In addition, it is recognized that bioengineering graduates should continually refine and enlarge their knowledge to keep pace with the rapidly expanding field of bioengineering. Therefore, learning environments were needed that provided all students with a core set of experiences that led to their fluent use of domain and engineering knowledge to solve novel problems and identify innovations.

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