Biotronic Engineering Curriculum Design:

Integrating Electronic Engineering and Applied/Health Sciences

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***Abstract*— A specialised major in Biotronic Engineering that meets the needs of health care industry was offered at Auckland University of Technology (AUT). The Biotronic Engineering major focuses on integrating electronic and computer systems engineering with human biology and applied sciences to solve problems related to medical systems and devices. Moreover, it covers the design, build and maintenance of medical instrumentation and devices that save people's lives or help keep them alive. This is a four year Honors degree designed for students who wish to become professional engineers with special knowledge of medical instruments and healthcare.**

***Keywords*—Curriculum Design; Biotronic Engineering; Engineering Qualification.**

I. INTRODUCTION

The developer of engineering education curriculum would consider current global issues through the design, update and review of the curriculum in a specific engineering program [1]. Moreover, healthcare assisted technology and sustainable development of medical devices are some of the challenges that a Biotronic Engineering curriculum should address. The outcome based education and sustainable development aspects can be also included in the objectives and outcomes of the Biotronic Engineering program.

The Biotronic Engineering major deals with the integration of electronics and computer system engineering curriculums with human biology and healthcare. It is a cross-disciplinary program with about 70% overlap with the existing electronic engineering program at the department of Electrical and Electronic Engineering, AUT. The research expertise of the staff in the department lies in signal processing, medical imaging, biomechanics, wireless sensor network, communication and biomedical instrumentation.

The program is supported by the AUT School of Applied Sciences by the inclusion of Organic Chemistry and Human Anatomy and Physiology based subjects. These core laboratory based subjects will provide necessary chemistry and biology backgrounds that are vital to the knowledge and skills of Biotronic Engineering students.

The curriculum is designed to provide a broad based knowledge in Biology within the context of the existing Electrical and Electronic major approved by the Institute of Professional Engineers of New Zealand (IPENZ). This is a unique program within the New Zealand context with its focus on the application of electronics and computer system engineering in the area of medical devices and healthcare.

The students will be seeking to gain a Bachelor of Engineering (Honors) qualification in Biotronic Engineering that will prepare them for both electronics and biomedical engineering related projects and jobs. The aim of the major is to develop an undergraduate program and produce resourceful engineers, who are able to work in interdisciplinary teams and healthcare industry.

The Biotronic Engineering major was approved by Program Approval and Review Committee (PARC) at the AUT University in 2008. The initial plan was to apply for a funding opportunity through Innovative and Development Fund (IDF) of Tertiary Education Commission (TEC) of New Zealand to extend the proposal for a larger number of admissions and establish a department of Biotronic Engineering. However, due to the cancellation of this grant, the initial proposal was restructured to limit the number enrolment to five in the first year and offer the major within the department of Electrical and Electronic Engineering, AUT.

The proposal was first submitted to Committee on University Academic Programs (CUAP) in September 2008. The new major generated considerable discussion and diverse comments from the other New Zealand Universities. These included the varied positions that there was not enough electronics, human biology or mathematics in the program of study. As an outcome of the discussions AUT withdrew the proposal from the table at the CUAP meeting in 2008.

After further consultation across the sector, particularly with the Australasian College of Physical and Engineering Scientists in Medicine (ACPESM), the curriculum developers have worked closely with ACPSEM and modified the proposal based on their recommendations. Changes have included: the introduction of a General and Organic Chemistry course in year 1; a reduction in the number of biology courses, with a shift in content to ensure all areas necessary for a Biotronic Engineer are adequately covered; the introduction of two new level 7 courses in Signal Processing and Biomedical Instrumentation to underpin to two level 8 courses in these key areas. The revised proposal was approved in the 2009 round of CUAP.

The proposal was supported by the School of Applied Sciences, School of Engineering, the Institute of Biomedical Technologies (IBTech), the Knowledge Engineering and Discovery Research Institute (KEDRI), the local hospitals, professional bodies and healthcare industries.

This major was offered to commencing students in the years 2010 to 2012 but it was put on-hold in 2013 for evaluation and cost-benefit analysis of running the program. Students currently enrolled will graduate over the period 2013-2015. IPENZ accreditation will be sought for this program in due course to cover the students who are already enrolled in this major. It is expected that the program will be reintroduced by 2015 after completing the evaluation and cost-benefit analysis.

In the next section, the background motivation behind the curriculum development of the major is described and in the sections that follow, the curriculum structure and teaching methods of the proposed undergraduate program are described.

II. BACKGROUND

A. Motivation

Educating in the multidisciplinary courses that go beyond the traditional engineering curriculum is a growing need in biomedical engineering disciplines [2]. A course in Bioengineering System Design offered at the University of Denver (DU) was among a number of similar reported courses for educating engineering students. The course was running by a multidisciplinary team across Engineering, Education and Psychology Faculties at DU as well as Denver Health Medical Center and was aimed to develop projects that would aid persons with disabilities [2]. There are many universities which have recently started offering programs of similar kind by incorporating science, engineering and medicine. For example, Nanyang Technological University, Singapore [3], has recently begun offering an undergraduate degree in Bioengineering, where the students can specialize either in Bioinstrumentation and Bioelectronics or Biomaterials and Tissue Engineering. The main objective of this degree is to effectively apply concepts in biological, physical and medical sciences, as well as engineering principles, to the practice of biomedical engineering.

The students educated through the Biotronic Engineering program are trained across a multidisciplinary program offered by electronic engineering and applied science departments at AUT University. The program educates students and gives them the knowledge and skills to design, build and maintain medical instrumentation and devices that save people's lives or help keep them alive. In addition, they should be able to prepare technical reports and analyze societal impact of medical devices and new technologies in conjunction with healthcare.

A limited development cost and resources was needed when the integration of existing Electronic and Applied Sciences/Health courses in the curriculum were considered.

B. Rationale

The major of Biotronic Engineering is an innovative, interdisciplinary, interdepartmental curriculum that has been established for the first time in New Zealand at undergraduate level.

The Biotronic Engineering graduates have the opportunity to continue their postgraduate study at the AUT research institutes, at the new master of engineering program in medical devices of University of Auckland, or other universities in New Zealand or elsewhere.

The proposed major aims to meet a shortfall in the number of qualified engineers trained in the design and maintenance of medical devices. It employs computational and informatics tools and their applications in medical or clinical research, health care practice and healthcare sectors. The shortfall has been established through a number of dialogues between AUT, representatives of the electronics industry and health service providers of New Zealand. Biotronic engineers of the future will use electronics to improve health care and health services and provide high-quality, innovative and cost-effective services that enable safe and effective patient care.

C. Supports

A panel from ACPSEM met with the curriculum development team from AUT to discuss the proposed major in November 2008 at Christchurch. The panel consisted of six members of the College who were a mix of biomedical engineers from hospitals, biomedical industry and universities. Four were members of IPENZ (including 2 fellows) and one was a member of Engineers Australia. Two were the heads of the larger (and probably largest) hospital medical physics and biomedical engineering departments in Australasia.

The role of panel members was strictly to act as representatives of ACPSEM and as such they considered the proposal only in terms of that professional/industry body acting to ensure that the graduates will be properly prepared for a career in Biotronic Engineering.

The panel supported the concept of a Biotronic Engineering major in New Zealand subject to some changes in the curriculum to gain the approval of the College. The panel was unanimous in the view that there is a place for its graduates in hospitals and the biomedical industry.

Moreover, the following letters of support were obtained from:

- Chief Technology Officer of Tru-Test Limited, New Zealand, who was also Chairman of Advisory Board, Department of Electrical & Electronic Engineering, AUT University (20 Feb 2008).
- R&D Manager, BrainZ Instruments Let., New Zealand (20 Feb 2008).
- Vice President Research & Development, Fisher & Paykel Healthcare, New Zealand (5 May 2009).
- Chair of ACPSEM AUT BE Biotronic Engineering Review Panel, ACPSEM NZ Branch Spokesperson on Education (17 April 2009).
- Head, Materials Technology Division, Director, Nanoscience & Nanotechnology Cluster (NanoCluster), Nanyang Technology University.

- Head, Semiconductor Optoelectronics and Nanotechnology Group, President, IEEE Nanotechnology Council Associate Vice-President, IEEE Lasers and Electro-Optics Society Convenor, Australian Research Council Nanotechnology Network, Director, Australian National Fabrication Facility, ACT node, Research School of Physical Sciences and Engineering, Australian National University
- Product Development Manager, Fisher and Paykel Healthcare, New Zealand.

III. Curriculum Structure

The results of a study indicate that engineering curriculum should focus more on innovation and provide engineering practice opportunities [4]. Moreover, it was concluded that the curriculum structure should be optimized and professional core courses should be reinforced [4].

The Biotronic Engineering is a four year full time program of study that shares a common first year with other existing engineering majors. This year provides engineering students with the necessary grounding in mathematics and computational techniques, workshop practices, including health and safety, and communication skills. Biotronic Engineering students will also take a General and Organic Chemistry course which replaces the core Engineering Workshop Practice course. These students will be required to cover workshop practice as an additional non credit bearing course. Core courses are also delivered in the second and third years: engineering mathematics and computation courses extend students' mathematical and computational techniques within the context of engineering; engineering management courses examine the role of the engineer in society and consider professional ethics, environmental engineering, sustainability issues, research ethics and principles of management and leadership as they relate to engineers and engineering functions.

The Biotronic Engineering core units consist of 240 cross-disciplinary points of which the students will be asked to select 30 points of elective courses.

Students commence their major area of study in the second year. The Biotronic Engineering major has been structured to give students a sound knowledge of human physiology, medical terminology, computer systems engineering and electronics technology. Among the proposed courses, a total of 30 points covers human anatomy and physiology. Biotronic engineering students will also have the opportunity to supplement their core program of study with up to 30 points of elective courses in their third and fourth year. Elective courses available at this stage would include Bioinformatics, VLSI Circuits, Systems and Technology or Intelligent Systems Engineering. However, it has been suggested that Bioinformatics course should be considered as a specialized compulsory course in year 4 of the major.

All students undertake a capstone 45 point industrial research project in the fourth year of study designed specifically to address the requirements of their chosen major. The final project course is a supervised program of study that consolidates and integrates the students' learning by providing the opportunity to apply acquired competency to case studies, practice situations or research questions.

In addition to successfully completing all the courses students are required to complete a minimum of 800 hours of planned supervised work placement prior to graduation. The aim of the work experience is to expose students to the engineering practices and management systems in the work environment.

The modularized structure of the program, including a mix of practical and theoretical courses, and flexible delivery, will enable students to gain technical skills to meet industry requirements. Fig. 1, shows the curriculum structure of the Biotronic Engineering major. The courses are divided into four parts as below:

- "Common" courses for all students at Electrical and Electronic Engineering department.
- "Specialized" courses for all with special emphasis on applications related to the individual major.
- "Elective" courses that Biotronic Engineering students are able to select from a wide range of courses.
- "Biotronic" courses that offer specifically to the Biotronic Engineering students.

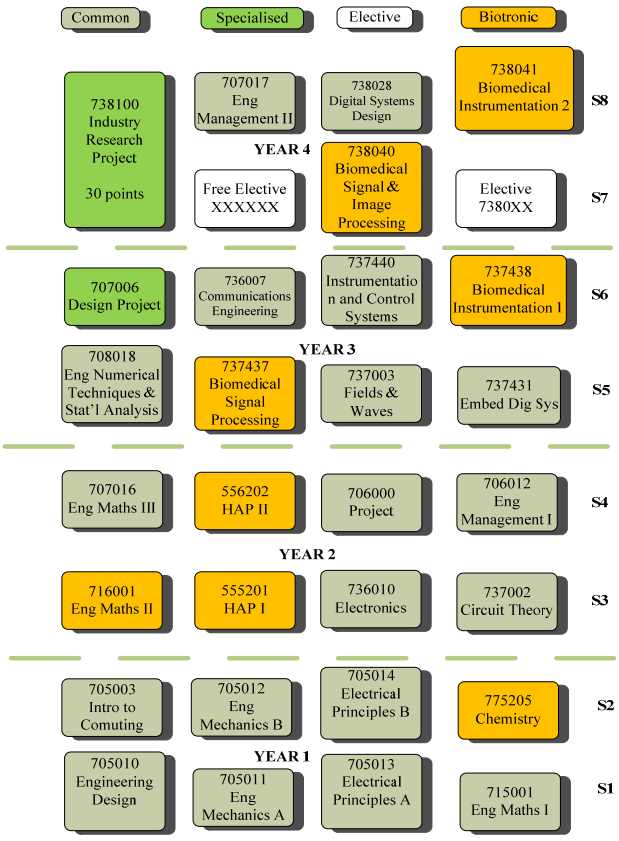

Fig. 1. The final version of the proposed Biotronic Engineering Structure.

Most courses carry 15 points and typically have 2 to 3 hours of lecture and 2 hours of lab per week, total of 48 to 60 contact hours per semester. In addition, students are expected to spend a time equivalent to 150% of the contact hours in the form of self directed learning.

Each paper that the students study has specific learning outcomes based on a 10 point graduate capabilities profile. The graduate profile capability is as follows and is part of the IPENZ requirement:

1. Knowledge of Engineering Sciences
2. Analysis and Problem solving
3. Design and Synthesis
4. Investigation and research.
5. Risk Management
6. Team Work
7. Communication
8. The Engineer and Society
9. Management and Financial
10. Practical Knowledge

IV. Teaching Methods

The direction of biomedical engineering has been changed in the 21st century and therefore requires a novel approach to teaching and course development [4]. The teaching of specialized Biotronic Engineering courses in year 3 and 4 has been based on a special approach in teaching of theoretical and experimental engineering problems in healthcare. The approach was aimed to facilitate mastery of information related to the advancement in biomedical engineering as well as improving the critical skills required for biotronic students.

These courses are taught by engineering staff with Biomedical Engineering specialties. The teaching of specialized Biotronic Engineering courses in years 1 and 2 has been taught by staff from biochemistry, human anatomy and physiology disciplines from School of Applied Sciences, AUT.

The field of Biotronic Engineering is a growing area and requires advanced techniques in teaching of the specialized courses. We have developed a pedagogical technique for teaching specialized courses by integrating lectures and seminars to maximize student participation in the classroom, internet research and independent study. The classical course material is covered in a lecture format and the recent technology or research is covered in the seminar format.

Most specialized courses in years 3 and 4 are divided into two parts: a lecture presented by professional staff and a series of seminars which are presented by the students. The lecture part provides a conceptual overview of the classical material in each course and also forms the basic background for the seminar part of the course [5].

For the lectures, the latest version of well-developed text books are used and in the seminar part, each student is responsible for the preparation of seminar content including the description of the state of technology in Biotronic Engineering related topics.

An important feature of the seminar part of the classroom learning process is the interaction of the presenting student with other students in the class and the role of the staff member in guiding the discussions [4]. Grades in most core courses are based on the student's course work with the weight of 30% and a final year exam in which questions are drawn from the entire course content with the weight of 70%.

V. Conclusion

The Biotronic Engineering major provides a great opportunity in New Zealand to enhance students' knowledge and critical skills required to design build and maintain medical devices and serve healthcare industry. It is an innovative study program as it was established for the first time in New Zealand at undergraduate level. The curriculum is designed by integrating two well-established curriculums of Electronic Engineering and Applied/Health Sciences in order to satisfy the requirements of the engineering accreditation panel, IPENZ, in New Zealand. Moreover, a limited development cost and resources was needed for introducing this major within the department of Electrical and Electronic Engineering, AUT University. However, external grants and supports would facilitate the establishment of such program with a larger number of students admitting to the program.

Acknowledgment

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