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BENCHMARKING OF BIOMEDICAL ENGINEERING TECHNOLOGY EDUCATION PROGRAMS IN CANADA

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INTRODUCTION

The Biomedical Engineering Program at the British Columbia Institute of Technology (BCIT) completed a program review [1] in 2016 which provided an opportunity to review the Program's relevance to the industry and services to learners. The constructive, collaborative, systematic, and research-based examination was leading to the development of an evidence-based action plan focused on program enhancements. The review included an in-depth study of the education design, industry demands and trends, student experience, quality of services, resources and facilities. Benchmarking of comparable BMET education programs was part of the process in the review.

BIOMEDICAL ENGINEERING PROFESSIONALS

According to the Bureau of Labor Statistics of the United States Department of Labor, "Biomedical Engineers apply knowledge of engineering, biology, and biomechanical principles to the design, development, and evaluation of biological and health systems and products, such as artificial organs, prostheses, instrumentation, medical information systems, and health management and care delivery systems" [2]. Industries which employ biomedical engineering professionals include medical equipment manufacturers and service providers, research and development organizations, pharmaceutical companies and hospitals. In Canada, there are two categories of biomedical engineering professionals – i) Biomedical Engineers (BME) and ii) Biomedical Engineering Technologists (BMET). A BME is usually a graduate from a bachelor degree university engineering program, while a BMET

is a graduate from an engineering technology diploma or advanced diploma program of a college or polytechnic institution. According to the Ontario Association of Certified Engineering Technicians and Technologists (OACETT), "A technologist is an individual who through academic training and experience in the application of engineering or scientific principles, is capable of assuming responsibility and exercise independent judgement in the practice of engineering or applied science technology. Typical activities include design, production, marketing, testing, quality control, estimating, surveying, inspection, diagnostic evaluation, supervision, management, technical sales and teaching." [3].

BIOMEDICAL ENGINEERING EDUCATION PROGRAMS IN CANADA

While over thirty Canadian universities offer degree programs in biomedical engineering, only seven post-secondary institutions offer BMET diploma programs in Canada [4]. Table 1 lists these 7 BMET programs and their respective official websites.

Table 1: BMET Education Programs

Name of Institution	Province	Official Program Website
British Columbia Institute of Technology (BCIT)	British Columbia	https://www.bcit.ca/study/programs/5050diplt
Norther Alberta Institute of Technology (NAIT)	Alberta	http://www.nait.ca/program_home_76175.htm
St. Clair College (SCC)	Ontario	http://www.stclaircollege.ca/programs/postsec/biomedical/
Centennial College (CC)	Ontario	http://www.centennialcollege.ca/programs-courses/full-time/biomedical-engineering-technology/
Durham College (DC)	Ontario	http://www.durhamcollege.ca/program/s/biomedical-engineering-technology
École Polytechnique de Montréal (EPM)	Quebec	http://www.polymtl.ca/etudes/certificats/cheminement/biomed.php
College of the North Atlantic (CNA)	Newfoundland & Labrador	http://www.cna.nl.ca/programs-courses/Show-Program-Details.aspx?program=49

The Canadian Technology Accreditation Board (CTAB) under the Canadian Council of Technicians and Technologists published the national technology benchmarks in biomedical engineering technology [4] which includes the graduate competencies and program criteria. A similar set of learning outcomes was adopted in 2015 by the Canadian Technology Accreditation Board under the Technology Accreditation Canada [5].

Table 2 summarizes the characteristics of the Canadian BMET programs. Most of the information was gathered from the descriptive sections of the programs' webpages in early 2016. The course loading of the curriculum of each program are summarized in Table 3. They are clustered according to core competencies grouping of the AAMI guidance document for BMET academic curriculum development [6]. Relative course loading (in %) was based on the total program credits excluding practicum and the number of credits assigned to each cluster. All courses related to medical devices (medical imaging, medical laboratory, dialysis, etc.) are grouped under the "Biomedical Technology" cluster. Courses such as technology management, patient care, customer care and services, or ethics are grouped under "Professional Skills". Table 4 breaks down the biomedical technology cluster into their respective medical device specialties.

OBSERVATIONS

Except for the Montreal, Quebec program (ÉPM) which is at the certificate level, all the other programs graduate biomedical engineering technologists at the diploma or advanced diploma level. The Western programs (BCIT and NAIT) are 2-year programs while the programs from Ontario (CC, SCC and DC) and the North Atlantic (CNA) are 3-years programs.

The following are points of interest that jumped out during the review of curriculum of these BMET programs:

BCIT

- Aimed at the healthcare technology service and support sector as well as medical device design and development industry.

- There is a mechanical skills workshop for students to learn and practice basic hand tools and simple machine tools.
- A patient care course taught by nursing faculty on patient care, safety and infection control measures.

NAIT

- Physics and Chemistry are not provided as separate courses.
- Three courses (3 credits each) to cover X-Ray Systems, Diagnostic Imaging Systems, and Radiographic Image Acquisition and Management
- Separate courses for Medical Laboratory Instrumentation and Renal Dialysis

St. Clair's College

- Aimed at the medical equipment and supplies industry, as well as service
- Program vocational outcomes include photonics and lasers, as well as dialysis and water treatment equipment
- General physics followed by 3 courses covering concepts of mechanics (statics, kinematics, biomechanics), biomaterials and tissue biomechanics
- Statistics course related to Quality Control
- Networking is spread over several courses

Centennial

- Generally seems to focus more on systems level applications
- LabView used to illustrate and practice instrumentation concepts in ETEC-203
- Networking is spread over several courses

Durham

- Extra time is spent on soft skills (career planning and development, customer care and service) and electives.
- More time on same topics spread over several courses. For example, the following topics are spread over more than one course: devices, networking, dialysis, imaging, safety standards & risk management.

École Polytechnique de Montréal

This program offers a certificate under two different options:

1. Information Systems (IT). This is 2.5 year part-time program catering to the needs of technologists who plan to be mainly active in the IT sector. This stream has no practicum (course-based only).

Table 2: Canadian BMET Education Program Profile

	BC Institute of Technology	N. Alberta Inst. of Tech.	St. Clair College	Centennial College	Durham College	College of North Atlantic	École Polytechnique de Montréal	
Program Name	Biomedical Engineering	Biomedical Engineering Technology	Biomedical Engineering Technology	Biomedical Engineering Technology	Biomedical Engineering Technology	Electronics Engineering Technology (Biomedical)	Biomedical Technology – Electronic Instrumentation	
Level/ Credential	Diploma	Diploma of Technology	Advanced Diploma	Advanced Diploma	Advanced Diploma	Diploma of Technology	Certificate (IT)	Certificate (Hosp. Int.)
Duration	2 years	2 years	3 years	3 years	3 years	3 years	2.5 years (part time)	1.5 years (full time)
Total Credits	129.5	79.5	120	140	130	150	39	27
Alternative Duration	---	---	---	2 yr diploma w/ College EE	1 yr diploma w/ BEng (EE)	---	---	---
Entrance Requirements	Engl12 Math12 or Pre-Calc 12 Phys 11 or 12 Chem 11	Engl 12 Math 12 or Pre-Calc 12 Phys 12 <u>or</u> Chem 12	Engl 12 Math 12 Biol 11 or 12 (recommended)	English 12 Math 12	Engl 12 Math 12 Biol 11 Phys <u>and</u> Chem	Engl 12 Math 12 Science credits (no mandatory courses)	Diploma of College Study & Math 12	Electronics Diploma
Target Industry	Service/ Med. Device R&D	Service	Med. Equip and Supplies	Service	Service	Service	Service/ Manufactur	Service
Emphasis/ Strength	Med. Device Development	D.I., Med. lab	Biomechanics	Co-op	D.I., dialysis	---	IT – CAD	
Capstone project	Yes (1 semester)	Yes (1 semester)	Yes (2 semesters)	Yes (1 semester)	Yes	Yes, (2 semester)	No	No
Co-op	No (summer jobs facilitated)	Optional (1 semester summer job)	No	Optional Full Co-op	No	No	No	No
Practicum Length	5 weeks	1 month (plus 4 th semester field practice)	0	3 semesters	Work placement aft. final term	7 weeks	No	Eq. 9h/wk (summer)

Table 3: Program Course Loading Distribution

Course Credits (% of total)	BC Institute of Technology	N. Alberta Inst. of Tech.	St. Clair College	Centennial College	Durham College	College of North Atlantic	École Polytechnique de Montréal	
Level/ Credential	Diploma	Diploma of Technology	Advanced Diploma	Advanced Diploma	Advanced Diploma	Diploma of Technology	Certificate (IT)	Certificate (Hosp. Int.)
Total Academic Credits	129.5	79.5	120	140	130	150	39	27
Biomedical Technology	31(24%)	25.5(33%)	28(23%)	35(25%)	51(39%)	29(19%)	12(31%)	18(67%)
Electronics & Basic Skills	35(27%)	19.5(25%)	20(17%)	37(26%)	28(22%)	54(36%)	0	0
Information Technology	21(16%)	16.5(22%)	19(16%)	23(16%)	10(8%)	15(10%)	12(31%)	3(11%)
Anatomy & Physiology	8(6%)	3(4%)	8(7%)	7(5%)	3(2%)	5(3%)	3(8%)	3(11%)
Math	15.5(12%)	6(8%)	10(8%)	6(4%)	13(10%)	16(11%)	0	0
Physics	4(3%)	0	23(19%)	7(5%)	3(2%)	8(5%)	0	0
Chemistry	6.6(5%)	0	0	0	0	8(5%)	0	0
Communication	6.5(5%)	3(4%)	2(2%)	11(8%)	3(2%)	9(6%)	6(15%)	3(11%)
Professional skills	2(2%)	3(4%)	1(1%)	11(8%)	10(8%)	6(4%)	6(15%)	0
Electives	0%	0%	9(8%)	3(2%)	9(7%)	0%	0	0

Table 4: Medical Device Course Load Distribution

Course Credits	BC Institute of Technology	N. Alberta Inst. of Tech.	St. Clair College	Centennial College	Durham College	College of North Atlantic	École Polytechnique de Montréal	
Level/ Credential	Diploma	Diploma of Technology	Advanced Diploma	Advanced Diploma	Advanced Diploma	Diploma of Technology	Certificate (IT)	Certificate (Hosp. Int.)
Med Device & Instrumentation	13	4.5	18	7	22	14	6	9
Diagnostic Imaging	5	9	4	4	8	0	3	4.5
Renal Dialysis	0	3	0	8	8	0	0	0
Med. Lab. Instrumentation	5	3	0	0	0	0	3	4.5
Med. Computer Network	5	4.5	5	9	8	4	15	3
Total	28	24	27	28	46	18	24	21

2. Hospital Integration (Hosp. Int.). This is 1.5 year full-time study program for those technologists from non-BMET (i.e. Electrical Engineering) background who need to get a deep exposure on clinical aspects of the BMET profession.

College of the North Atlantic

- Biomedical Instrumentation I uses site visits to local health care facilities to supplement lab experience
- Basic science courses are offered at the high school level. Transfer credits are granted to students with appropriate high school credits.

Unlike most programs, where one course credit is defined as 15 contact hours, Centennial College and College of the North Atlantic assign course credits to reflect student workload. All diploma programs contain foundation courses in anatomy and physiology, mathematics, communications, computer, electronics and a capstone project. All programs except NAIT and ÉPM, have one or more physics courses. The following courses are noteworthy in that they are not offered in all program although some of the contents may be partially covered in other courses:

- Overview of Profession (SCC, DC, CNA)
- Project Management and Financial Management (CNA), Biomedical Technology Management (DC), Project Management and Equipment Acquisition (NAIT), Biomedical Management (NAIT)
- Ethics (SCC), Global Citizenship: From Social Analysis to Social Action (CC)
- Problem Solving Methodology (ÉPM)
- Customer Care and Service (DC), Biomedical Product Sales and Service (CC), Employment Skills (CC)
- Patient Care (BCIT)
- Microbiology and Infection Control (CC)
- Medical Terminology (DC, CNA)
- Chemistry (BCIT, CNA)
- Embedded Linux (CNA)
- Engineering Graphics (CNA)
- Fabrication techniques (CNA), Electronic Prototype Manufacturing (BCIT), Mechanical Skills Workshop (BCIT), CAD essentials (SC, DC, CNA)

- Electromechanical systems (including pneumatics) (CNA)
- Biomechanics (SC, CC), Biomaterials (SC)
- Photonics (CC)
- Research and Development (CC)
- Introduction to ISO 9001 (ÉPM), Medical Device Standards (BCIT)
- Statistics and Quality Control (SC), Statistics for Biomedical Engineering (BCIT)
- RF Communication (CC), Electrical Controls (DC)

CONCLUSIONS AND FUTURE WORK

This benchmarking exercise on biomedical engineering technology education programs provided perspectives of industry focus, program structure, curriculum characteristics, specific features, and course loading of these Canadian programs. All except the ÉPM certificate programs cover in general the core competency grouping of the AAMI guidance document for BMET academic curriculum [6]. The information from this review, together with analysis of the industrial trends, job requirements, feedbacks from students, faculty, and industry stakeholders, are used in formulating the curriculum change, which is the next phase following the BCIT Program Review.

REFERENCES

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