Academic Programs in Clinical Engineering in Canada

Varsha Chaugai*, Timothy Zakutney*†, Adrian D.C. Chan* and Andy Adler*
*Department Systemsl and Computer Engineering
Carleton University, Ottawa, ON, Canada
†Department of Biomedical Engineering
University of Ottawa Heart Institute, Ottawa, ON, Canada

***Abstract*—Clinical engineering is a discipline of biomedical engineering that encompasses application of technological solutions to clinical problems. The advancement of medical technology in diagnostic, therapeutic, and rehabilitative care has made clinical engineers an integral part of the health care system. They play a vital role in ensuring safe and effective use of medical equipment and enhancing patient care by successfully bridging the gaps among clinical staff, hospital administrators and engineering personnel. It is therefore important that clinical engineers have expertise in healthcare, engineering, economics, management, and administration for an effective design and operation of a clinical environment.**

The demand of clinical engineers in the Canadian Health Society is increasing. To our knowledge, there are in total five university institutions across Canada that offers a clinical engineering program. We conducted a survey on the structure of the clinical engineering program in these universities. This paper presents an analysis of the survey results to bring into light the academic approach and activities provided to the future clinical engineers in Canada.

I. Introduction

The involvement of engineers in the health care system started in the 1960s when the use of complex and technologically advanced medical devices began to introduce issues concerning patient safety, proper device use, and maintenance [1]. Since then, a specialized engineering discipline, clinical engineering (CE), has evolved to implement engineering practices and techniques exclusively in a clinical environment.

The increasing dependency of clinicians on biomedical devices for diagnostic, therapeutic, and rehabilitative patient care has expanded the responsibilities of clinical engineers beyond technology repair, maintenance and management [2]. The role of clinical engineers in a medical arena today involves everything that requires engineering expertise and methodology to facilitate safer, more economical, and higher quality patient care. Clinical engineers interface with the health care practitioners, hospital administration, and other engineering and technical personnel to perform a wide spectrum of responsibilities that include clinical facility design, technology assessment and procurement of new medical equipment, vendor service management, integration of medical devices into existing systems, technology maintenance and repair, standards and regulatory compliance, inspection, safety and risk management, clinical training concerning the effective use of equipment, and research and development [2]. Today, most hospitals in developed countries have incorporated the above tasks within a centralized clinical/biomedical engineering department comprising of clinical engineer as a manager, director, or leader, and biomedical equipment technicians and technologists. Additional personnel may include administrative assistant(s), and Information Technology Analysts. This team's expertise has led to the use of hospital's technological resources for the patient's greatest benefit.

The health care system in Canada has accepted clinical engineers as a part of the hospital's workforce. Despite the constrained funding of the health care system through the federal and provincial government, the clinical engineering departments have brought about a tremendous improvement in the quality of patient care within hospital budgets. With the recognition and reliance on clinical engineering functions within the clinical setting, it is important that the engineers are trained under proper guidance and have experiential education to successfully carry out their role as a clinical engineer and technology leader. To be considered as a clinical engineer in Canada, it is required that the engineer possess a P.Eng.(ing. in Quebec) registration along with a graduate degree in clinical engineering. In Canadian academia, clinical engineering was first introduced in 1972 at University of New Brunswick (UNB) as one of the courses offered for students enrolled in the Masters of Engineering (M.Eng) program. In 1984, clinical engineering emerged as an academic discipline at the University of Toronto (UofT). Today there are a total of five universities across Canada that provides a graduate degree in CE: University of Toronto, University of New Brunswick, University of Saskatchewan (USask), University of British Columbia (UBC), and Université de Montreal (UdeM). This paper describes the academic approaches undertaken by these universities as they prepare the prospective clinical engineers to translate their engineering, administrative, and life sciences knowledge for the support of clinical applications. For this, we conducted a survey and the information obtained from it is presented in this paper.

II. Methodology

The following data was gathered from the five universities that offer a graduate degree in CE:

1) Degree Prerequisites
2) Selection Process

3) Credit requirements
4) Course curriculum
5) Applicants applied, approved and registered
6) Arrangement for internships
7) Affiliation with medical schools, health administration and business
8) Career path of the CE graduates

TABLE I: List of universities offering Clinical Engineering with their respective URLs

Universities	URL
UofT	http://ibbme.utoronto.ca/
USask	http://www.engr.usask.ca/departments/biomedical/
UBC	http://www.bme.ubc.ca/
UNB	http://www.unb.ca/research/institutes/biomedical/students-and-researchers/internship.html
UdeM	http://www.igb.umontreal.ca/liste-cours/cours-udem.html

Data were obtained via the university websites (Table I). The appropriate program coordinator at each university was also contacted directly via email with a questionnaire for these data. The information collected both online and through the program coordinators occurred between September, 2012 and October, 2012.

III. Results

A. Degree offered, prerequisites, and selection process:

Clinical Engineering in Canada is offered as a Master's program usually denoted as M.Eng. The UofT, in particular, awards Masters of Health Science (MHSc) to its student enrolled for CE program and also have extended the CE program to the Ph.D level. The CE program is intended for students that have an undergraduate degree in Engineering or closely related scientific discipline. UofT and UdeM have similar selection processes where students are initially shortlisted based on their undergraduate grades, then followed by an interview in order to make the final selection. In USask, students who apply for the program are directed to the staff at Royal University Hospital (RUH) who is in charge of the internship program. Only if a position is available is the student considered, provided all other academic criteria are met. At UNB, clinical engineering is offered more as a course than a degree program. Students interested in pursuing a clinical engineering career have to undergo a clinical engineering internship program. Only those students enrolled for M.Eng and who fulfill all the M.Eng course requirements are eligible for the internship.

B. Degree Requirements:

All CE master's programs are typically 2 years. CE Ph.D programs offered in UofT take 4-6 years. For the master's degree, students are expected to enroll full time and complete the academic courses as well as an internship. The same requirement applies to Ph.D program as well; however the internship is replaced by a research thesis. Typically 6-8 courses are required for this program along with a 3 months to 12 months internship, depending on the institution, refer to Table III. Apart from courses and internship, the degree requirement in UofT, and UdeM entails completion of a thesis/project.

C. Applicants:

TABLE II: Statistics on the applicants for clinical engineering program

	UofT	USask	UBC	UNB	UdeM
# of Applicants per year	61	1	NA	1	10
# of Accepted Applicants per year	20	1	12	1	7-9
# of Registered Applicants per year	19	1	12	1	All the accepted applicants register for the program

USask and UNB accept students solely based on the number of positions available in the hospitals for internships. In the past, they have accepted no more than one student for this program. UofT usually accepts 20 applicants per year for MHSc and 5 for Ph.D. UoM enrolls 7-9 students per year. We could not get any quantitative information regarding number of applicants from UBC (Table II).

D. Course Curriculum:

1) *Courses:*
The courses offered at each these universities for CE varied. The core courses offered for this discipline were typically clinical/biomedical instrumentation, ethics in human/animal research, human physiology related to biomedical engineering and a graduate biomedical engineering seminar. The elective courses offered at these universities were an integration of various other disciplines such a computer, electrical, biomedical, mechanical engineering, biology and business management.

TABLE III: Course Structure of CE

Universities	Degree Issued	# of courses	Thesis	Internship
UofT	MHSc (Ph.D)	6	Yes	Yes (1225 hrs)
USask	M.Eng (C.E)	8	No	Yes (8 months)
UBC	M.Eng	7-8	No	Yes (4 months)
UNB	M.Eng	8	No	Yes (3 months)
UdeM	M.Eng	7	Yes	Yes (4 months)

2) *Intership:*
The internship program is mandatory for students enrolled in a Clinical Engineering program. There is an

internship during the 2-year program which is for 6-8 months and students work on projects in the clinical environment that translate their classroom engineering knowledge to the practical side of health care technology. These universities collaborate with the hospitals typically in their provinces and the department offering CE is responsible for facilitating internships. During the course of the internship, students are generally provided with a stipend from the hospital's biomedical service budget except at UNB where the pay is provided by the UNB Institute of Biomedical Engineering.

3) *Thesis:*
The thesis or project requirement is mandated only at UofT and UofM. The thesis contributes to the number of credit hours and the topic should be within the scope of CE.

E. Affiliations:

Results from our survey indicated no affiliation of these universities with health administration, business, or medical schools. They only had formal arrangements with hospitals for facilitating their internship programs. The universities make arrangements only with their provincial hospitals. The internships have mainly been carried out only in RUH, Saskatoon, for USask students, and Saint John Regional Hospital, Saint John, for UNB. UofM has partnered with 10 hospitals in Quebec and only UofT has provided an opportunity for internships outside Canada in institutions such as Massachusetts General Hospital, Brigham and Women's Hospital (USA), World Health Organization (Geneva), Bionic Ear Institute (Australia).

F. Career path for the CE graduates

Most of the universities were not in contact with the students after they graduate; however the goal for most CE students is to look for job in a hospital or industry. UofT reported to have 25.4% of their graduates working in industry, 45.4% in hospitals, 16.4% are medical doctors (or training to be MDs), 7.3% in consulting and 5.45% are in academics pursuing Ph.D.

IV. Discussion

The CE program in Canadian universities share similarities in the top level approach, in that the program comprises of courses, an internship and a thesis/project. Most of the universities have based their course curriculum around biomedical engineering and this is adequate only if the role of CE entailed dealing only with medical devices. A clinical engineer has been defined by American College of Clinical Engineering as a "professional who supports and advances patient care by applying engineering and managerial skills to health care technology" [3]. Based on this definition, the curriculum that completely excludes administrative, business, and information technology programs may not suffice in preparing the clinical engineer for the role they are to perform in a health care setting. The key ingredient to hone a complete clinical engineer is to supplement the present course curriculum with the elements of business administration and management. Another area where this program structure is lacking is education on safety and risk management. In a clinical environment, clinical engineers are constantly exposed to the issues of medical equipment safety, possible hospital hazards, and regulations and standards. The academic approach in clinical engineering should also address safety, risk management and different safety standards and regulations.

The current provision of internship provided to the students from these universities is laudable as they introduce the student into a professional setting; however, it may be ideal if the internship arrangements are made for 2-4 months at a separate institution and/or with separate projects so that the students are thoroughly exposed to different clinical scenarios and work place cultures, develop interpersonal skills, and also understand the clinical engineering practices of different hospitals. Most of the jobs for clinical engineers today require the individual to be certified as clinical engineer by the Canadian Board of Examiners for Clinical Engineering Certification. For now, the universities do not provide the students with any kind of preparatory guides for this certification; however, we feel that guidance for this qualification should be provided to the students to better prepare them for this career path.

The academic goal set for CE in Canada is well organized but more reform in the approach is required so that the education provided complies with the present and future expectations of the health care system from these engineers. The program should expand from scattered independent courses to a properly knitted design that not only brings the health care system and industry closer to the classroom but also provide students with the knowledge to become successful professionals.

V. Conclusion

Clinical engineering as a profession in Canada has undergone a drastic reform in its role and scope over the years. The expansion in their duties from repair and maintenance to technology planning, decision making, managing, and evaluating has brought about positive change in the health care process. This change in role must also be reflected in the academia that trains the future clinical engineers so that they are able to efficiently fulfill the ever-growing hospital/industrial demands. The intent behind this paper was to reflect on the clinical engineering education and encourage the institutions to synergize medical, business, health administration, regulation, and safety management into the clinical engineering program to produce better professionals.

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REFERENCES

[1] Y. David and J. Bronzino, *Clinical Enginnering*, in Principles and Applications in Engineering, 1st ed. USA: CRC Press, 2003.

[2] J. F. Dyro, *Clinical Enginnering Handbook*,7th ed. Amsterdam: Elsevier Academic Press, 2004.

[3] Americal College of Clinical Engineering, *Clinical Engineer (defined)*, Online. Accessed:15 March 2013, Available : http://www.accenet.org/.

APPENDIX
SURVEY QUESTIONNAIRE

1) Location
2) Degree Prerequisites
3) Degree Issued
4) Number of years required to complete the degree
5) Number of credits required to complete
6) Thesis requirement for the program
7) Number of applicants per year
8) Number of accepted applicants per year
9) Number of registered applicants per year
10) Brief summary of approval selection process
11) Course curriculum for the program including structure
12) What happens to students generally after the degree is awarded?
13) Is there any formal discussion preparation for Certification as a Clinical Enginner?
14) Is there any formal affiliation with the following specialized school/program:
    a. Medical
    b. Business
    c. Health Administration
15) Do you have any historical statistics in terms of number of graduates per year?
16) When was the program started?
17) Are there formal arrangements/agreements with hospitals (local and out of town hospitals)?
18) How many internships through 2 years?
19) Are the students paid a stiphend?
20) Who pays for the students?
21) Who makes the arrangements for the internships?
22) What external funding is available for students (non-internship stipend)?