Essential elements of a modern Clinical Engineering Internship

*Ottawa-Carleton Institute for Biomedical Engineering*

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Abstract— The Ottawa Carleton Institute of Biomedical Engineering has offered a clinical engineering graduate degree program since 2013. To date, this program has graduated 9 students, and has 3 pending graduations. The internship program follows a robust rubric and tutorials that covers the scope of the American College of Clinical Engineering Body of Knowledge preparing students for the current demands of the profession. 2024 will include 3 Ottawa internships and 1 new internship Toronto, growing the program to 4. We hope this rubric to be adopted by other international programs wishing to establish a similar foundation for a modern Clinical Engineering Internship.

Keywords— internship, OCIBME, training, education

INTRODUCTION

Clinical Engineering (CE) is relatively a young profession of ~60 years [1] which has purpose and unquestionable need with the proliferation, and complexity of medical equipment in healthcare. The commonly accepted definition of a clinical engineer by the American College of Clinical Engineering (ACCE) remains a “professional who supports and advances patient care by applying engineering and managerial skills to health care technology” [2]. While the demand of healthcare technology has expanded in hospitals, and clinicians are very dependent on equipment to apply their skills [3], the growth of the clinical engineering profession has been somewhat stagnant. The need to develop clinical engineering skillset is imperative to ensure the proper development of not only the field but of the workforce of tomorrow. Clinical Engineering training programs that deliver these skillsets need to be advertised and supported to sustain the future requirements of health technology management in hospitals [4].

Background

The Ottawa-Carleton Institute for Biomedical Engineering (OCIBME) was established in 2006 and is a collaboration between the University of Ottawa and Carleton University. It draws on the expertise of prominent researchers and medical professionals from hospitals and well-established medical research institutions [5]. The Institute has offered a Master of Engineering (M.Eng.) with a Concentration in Clinical Engineering since 2013, with its first graduate [4]. The OCIBME clinical engineering program remains one of the last bastions in Canadian education training graduate students in the field of clinical engineering. In the last decade, clinical engineering programs at the University of New Brunswick, University of Saskatchewan, University of British Columbia and most recently the University of Toronto (UofT) have either cut the program curriculum, eliminated clinical engineering program ‘branding’ on their website or have suspended admissions [6]. The Université de Montreal offers a “Maîtrise option Génie Clinique” (Masters clinical engineering option) [7] the only other known school in 2024 to offer a specialized clinical engineering program, and the only one in French language.

Students interested in the program apply to the OCIBME school of choice and once accepted, answer the call for applications for the Clinical Engineering concentration. A commonly accepted requisite of a Clinical Engineering focused master’s degree is the internship. The OCIMBE has 3 main partners including: The Children’s Hospital of Eastern Ontario (CHEO), University of Ottawa Heart Institute (UOHI) and The Ottawa Hospital (TOH).

The concept of an internship is not new and has been well described by others since the early 1970s focusing on introducing the application of technologies from the hospital settings and direct involvement in clinical research [8-13]. More recently others tried to focus primarily on the design, development, implementation, and regulatory affairs of clinical equipment and devices, as well as the health technology and hospital facility management [14, 15].

The education and training pathway for clinical engineers follows parallels to that of medical doctors; there is foundational academic study and complementary hands-on clinical internship [13]. The internships of the past describe important key objectives obtaining exposure to technology and often focusing on the design of equipment [11, 12]. Articles describe the focus of a clinical engineer solving clinical problems of the day. While the modern internship achieves the same primary principle converting the academic learning into relevant healthcare applications, it focuses on specific skills and the enhancement of personal attributes to produce a competent clinical engineering intern ready for the hospital setting [10].

Herein, the authors describe a clinical engineering Internship format that has been developed and refined into a rubric. It targets exercising foundational personal attributes and a comprehensive skillset used for modern clinical engineering challenges. We hope that this article will serve to enshrine the skills required for a modern-day clinical engineering internship and possibly assist others to mimic this model for another CE internship program.

## The Program Coursework

The OCIMBE Master’s program with concentration in Clinical Engineering requires 27 credits. Of these credits 15 are compulsory courses of 3 credits each that must be taken during the first year of the program. The courses include Biomedical Instrumentation, Medical Imaging Modalities, Introduction to Biomedical Engineering, Clinical Engineering, Fundamentals of Policy I: Policy Analysis and Biomedical Engineering Seminar. 12 of 27 credits are the Clinical Engineering internship and Clinical Engineering Project (6 credits each) and are the responsibility of the internship supervisor [16-17].

## Goals of the Internship

Internship Supervisors aim to provide clear objectives by formalizing the essential elements that substantiate a modern clinical engineering Internship into a rubric to prepare graduates for the demands of the profession and eventual certification in clinical engineering. One of the fundamental tenets is problem-based learning and personal goal exploration. Supervisors early on seek student interest to tailor the Internship to provide the best experience for both parties. Supervisors must meet the student where they are at when they start but aim to push students to their potential by the end. Mentorship is mutually beneficial, and Supervisors learn a considerable amount from their students as well and use this to amend and adapt future Internships.

## The Internship

The Internship begins following Winter semester and spanning 2 terms, Summer, and Fall. It is 8 months part-time onsite work, which translates to 650 hours of compensation. There is always more work than can be done onsite and the student is expected to continue learning offsite such as background reading, literature reviews and preparation for collaboration with supervisors, clinicians, and vendors. Internship placements often have a list of suitable graduate level projects.

The Internship is broken into 4 phases of 2 months each. There are no hard boundaries between the phases and each intern progresses through the phases at their own pace. The first two months, consist of project planning as the intern integrates into the hospital and most student focus is geared to set them up for project success. This can be a steep learning curve requiring considerable up-front support. It can be a student’s first exposure to a clinical setting, which can be intimidating and overwhelming. During this time, potential projects are discussed. The second phase is the project start such as background reading, meeting project partners and possibly vendors. This phase scopes and scales the project for the intern. The third phase is data collection and analysis, whereas the last fourth phase is closing the project, summarizing, and writing the project report.



Fig. 1 2023 Clinical Engineering Interns tour of Medical Device Reprocessing Department at The Ottawa Hospital

The intern completes two deliverables for grading and critique: an Internship Summary and Project Report. The Internship Summary details the comprehensive exposure (e.g. tutorials, clinical exposure, unique tasks, major project). Students are encouraged to keep log of their hours to provide a percentage of time relative to one another. It is also expected that the student will document their learning in a journal style: what did you expect? what was it actually? what did you learn? Etc. The Project Report is the second deliverable, a formal engineering report (mini thesis) and students must commit considerable effort to this task (40-55% of their time).

Although Interns have different experiences in their placements, they share their experiences and learn amongst each other. These bonds lay groundwork for professional collegiality post-graduation (Fig.1).

## Internship Rubric

The Internship rubric has various essential elements of a clinical engineering internship, including program objectives, duration, curriculum design, hands-on experience, mentorship, and assessment methods. These elements follow the ACCE Body of Knowledge (BoK) Certification Study Guide, literature, industry standards, and expert recommendations (Table 1).

By incorporating these elements into the design and implementation of internship programs, educational institutions, healthcare facilities, and industry stakeholders can ensure that interns receive a well-rounded experience that prepares them for the demands of the profession.

Table 1 CE Internship Rubric

|  |  |  |
| --- | --- | --- |
| Goal | Task | Examples |
| Clinical Exposure | Operating Room Procedures\* | Neuro/SpinalOrthopedicsCardiac (examples):* Electrophysiology,
* Cath Lab/Open Heart
 |
| Medical Device Reprocessing Department (MDRD) | Tour of MDRD |
| Eastern Ontario Regional Laboratory Association (EORLA) | Tour of EORLA Labs |
| Technical Exposure | Tech Work | Shadow Diagnostic ImagingSpend a day at each hospital shadowing techs (dialysis, labs, clinical, etc.) |
| Patient Safety | Incident Investigation | Complete (1) incident Investigation |
| Risk Management | Safety Alerts | Weekly Alerts, Hazards and Recalls |
| General Management | Policy | Draft at least one (1) department policy, guideline, or standard operating procedure |
| Service Delivery Management | CMBES Standards of Practice (SoP) | Select an area of the CMBES SoP and perform department audit. |
| Education | Advocacy | Education of Others about the Profession (e.g. ACCE, CMBES, CESO, etc.)Formal Definition of Clinical Engineer National/InternationalProfessional Engineer |
| Journal/Conference Publication (if possible) | Investigate CMBES, IEEE, Journal of Clinical Engineering, Global Engineering Journal |
| Presentation to Panel of Peers | Present Internship Summary at the Annual CE ConferenceParticipation in Monthly CESO Meetings |

Table 2 2023 Internship Tutorial Series

|  |  |
| --- | --- |
| Body of Knowledge | Topic |
| Technology Management | Unique Device Identifiers (UDI) |
| Computerized Maintenance Management System (CMMS) |
| Redevelopment Projects |
| Preventive Maintenance, Corrective Repairs, Incoming Inspections, Asset Disposal and Decommissioning |
| Service Delivery Management | How does Hospital Money Flow? |
| Capital Request Submission and Prioritization process & 5 Year Plan |
| Ins and Outs of Request for Proposals (RFP) + Technology Assessment |
| Setting the Budget, capital funding requests |
| Project Manager (PM) Toolbox: How does PM run RFP |
| Product Development, Testing, Evaluation, & Modification | Review of Health Canada Med Dev Regulations, Licenses, Pre/Post Market Surveillance, Special Access Program |
| IT/Telecom | Networking + Medical Devices |
| Cybersecurity |
| Medical Device Integration |
| Education of Others | Certification in Clinical Engineering, and other certifications |
| Roles and responsibilities of a clinical engineer |
| Facilities Management | Gases, Vacuum, Heating Ventilation Air Conditioning (filtration, pressures), Steam, Air Emissions |
| Risk Management | Alerts, Hazards, and Recalls |
| Just Culture, Reporting, and Incident Investigations, Canadian Medical Devices Sentinel Network and Vanessa’s Law |
| Radiation Safety |
| General Management | HR, Staffing, Performance Management, Unions, Accommodations, etc. |
| Creation of Policies, Standard Operating Procedures, Job Procedures and Checklists |
| Clinical Engineering Profession | What is a clinical engineer? [18] |
| Clinical Engineering Profession [19] |
| Clinical Engineering & Medical Devices [20] |
| Associations or Societies to explore in CE |
| Other | Infection control/PPE Session |
| Diagnostic Imaging Devices |
| Niche DI Equipment |
| Clinical Engineering in Scotland – International perspective |

## Internship Tutorial Series

An online tutorial series was created from May-December each year, where experts provide a 45–60-minute lecture for their area of expertise. This broadens the scope and enhances the learning from a larger group. The lectures are slotted into the ACCE BoK headings where possible. Table 2 provides a summary of our 2023 Tutorial Series.

Results

## Success of the Graduate Internship

The OCIBME Clinical Engineering Concentration (CEC) has had many iterations. The CEP has graduated 9 students from the Internship and at the time of writing this article will have another 3 in December 2023. 2024 will mark the 7th cycle of the Internship since its inception a decade ago. We are excited that an additional 4 students have already been selected for the May – Dec 2024 Internships.

Expansion of this Internship will continue to other cities such as Toronto that was dependent on the UofT Masters Health Science program. 2024 will mark a new opportunity for an intern to work with the University Health Network (UHN) in Toronto. We are excited to see this growth and conversations remain to expand to other willing placement organizations.

The Canadian Clinical Engineering landscape benefits from building a program and aspiring International Clinical Engineering programs can use knowledge from this established Internship program.

## Clinical Engineering Society of Ontario Conference

It is an expectation that all our students will present their final project report in front of a *panel of peers*. This is an important finishing step in the Internship to prepare the student to share their work. We want the students to be supported by their peers and challenged by colleagues on their work and perspectives. Prior to the pandemic, we worked with the Clinical Engineering Society of Ontario (CESO) to reserve time for the presentation of Internship work. Now, we work with the Canadian Medical and Biological Engineering Society (CMBES) to organize an online webinar of one hour where CE interns can present their contributions to the field of work.

## American College of Clinical Engineering Awards

Four Clinical Engineering Interns have won the ACCE student paper competition in the US/Canada Master Division 2020-2023 [21]. These awards clearly demonstrate of the caliber of students in the program, the strength of the Internship and the novel enhancements their work provides to CE departments. These award-winning papers are published in the Journal of Clinical Engineering, a renowned journal in the field of CE. This benefits intern resumes, the program, and the hospital.

## Post Graduate Alumni Leadership

The OCIBME CEC has built a strong alumni network and support network is a short time. More than half of our graduating students have obtained in-hospital clinical engineer jobs, and one has used this as a steppingstone into medical school. Our graduates are associated with the following organizations:

* Mass General Brigham, Boston, MA
* CHEO, Ottawa, ON
* McGill Medical School, Montreal, QC
* Sick Kids Hospital, Toronto, ON
* University Health Network, Toronto, ON

CONCLUSIONS

The Ottawa Carleton Institute for Biomedical Engineering created a Master of Engineering (M.Eng.) with a specialty in Clinical Engineering a decade ago. The authors have described the Clinical Engineering Internship of the graduate work. A summary of the goals, a formalized guideline, tutorial series and recent successes of the interns have been presented herein. 2024 will mark the expansion of the program to provide a 4th host at the University Health Network and enabling an additional Internship.

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Conflict of Interest

The authors declare that they have no conflict of interest.

REFERENCES

1. M. G. Ridgway, “The great 1970s debate on electrical safety-In retrospect,” *Clinical Engineering Handbook*, pp. 373–376, 2020.
2. “Clinical Engineer,” *Accenet.org*. [Online]. Available: https://accenet.org/about/Pages/ClinicalEngineer.aspx. [Accessed: 11-Jan-2024].
3. M. D. Schwartz, “The emerging field of clinical engineering and its accomplishments,” *IEEE Trans. Biomed. Eng.*, vol. BME-31, no. 12, pp. 743–748, 1984. 10.1109/TBME.1984.325233
4. V. Chaugai, T. Zakutney, A. D. Chan, and A. Adler, “Academic Programs in Clinical Engineering in Canada”,” *CMBES Proc*, vol. 36, no. 1, 2013.
5. “Ottawa-Carleton institute for biomedical engineering,” *Carleton.ca*. [Online]. Available: https://www.sce.carleton.ca/ocibme/. [Accessed: 11-Jan-2024].
6. “Biomedical engineering: Clinical engineering MHSc,” *Utoronto.ca*. [Online]. Available: https://sgs.calendar.utoronto.ca/biomedical-engineering-clinical-engineering-mhsc. [Accessed: 11-Jan-2024].
7. “Maîtrise option génie clinique,” *Institut de génie biomédical*, 02-Apr-2021. [Online]. Available: https://igb.umontreal.ca/etudes/programmes-en-genie-biomedical/maitrise-option-genie-clinique/. [Accessed: 11-Jan-2024].
8. J. D. Bronzino, “Clinical engineering internships: a regional hospital-based approach,” *J. Clin. Eng.*, vol. 10, no. 3, pp. 235–239, 1985.
9. J. D. Bronzino, “Clinical engineering education: the internship approach,” in *Images of the Twenty-First Century. Proceedings of the Annual International Engineering in Medicine and Biology Society*, 2003. doi: 10.1109/IEMBS.1989.96369.
10. A. M. Cook, L. E. Rose, and B. H. Barkalow, “Cost effective clinical engineering internships in community hospitals,” *J. Clin. Eng.*, vol. 3, no. 2, pp. 173–178, 1978.
11. D. J. Schneck and F. L. Brochu, “A Clinical Internship Program In Biomedical Engineering Part I: Objectives Of The Program,” *J. Clin. Eng.*, vol. 8, no. 1, pp. 51–60, 1983.
12. D. J. Schneck and F. L. Brochu, “A clinical internship program in biomedical engineering, Part II: Administration of the program,” *J. Clin. Eng.*, vol. 8, no. 2, pp. 123–134, 1983.
13. H. R. Weed, “Clinical engineering internship at Ohio State University,” *J. Clin. Eng.*, vol. 2, no. 2, pp. 133–135, 1977.
14. L. Kerr and S. Lalvani, “Development and Approval of a Master’s Program in Clinical Engineering at Miami University,” *J. Clin. Eng.*, vol. 48, no. 2, pp. 76–78, 2023.
15. E. Kwok, G. Marshall, and A. Chan, “How to prepare engineers in medicine and biology?,” in *2008 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* 2008. doi: 10.1109/IEMBS.2008.4649805.
16. “Master of engineering biomedical engineering and concentration clinical engineering < uOttawa,” *Uottawa.ca*. [Online]. Available: https://catalogue.uottawa.ca/en/graduate/master-engineering-biomedical-engineering-concentration-clinical-engineering/. [Accessed: 11-Jan-2024].
17. “Biomedical engineering < Carleton university,” *Carleton.ca*. [Online]. Available: https://calendar.carleton.ca/calendars/2019-2020/grad/gradprograms/biomedicalengineering/. [Accessed: 11-Jan-2024].
18. “ECOR 1055 J - BIOM A Ibey - Carleton university mediaspace,” *Carleton.ca*. [Online]. Available: https://mediaspace.carleton.ca/media/A+Ibey/1\_d6qqm8tk. [Accessed: 11-Jan-2024].
19. “ECOR 1055 J - BIOM MA-Janvier - Carleton university mediaspace,” *Carleton.ca*. [Online]. Available: https://mediaspace.carleton.ca/media/MA-J.mp4/1\_xu0xbag7. [Accessed: 11-Jan-2024].
20. “ECOR 1055 J - BIOM – T. Zakutney - Carleton university mediaspace,” *Carleton.ca*. [Online]. Available: https://mediaspace.carleton.ca/media/t/1\_0m889nlp. [Accessed: 11-Jan-2024].
21. “Student Paper Competition,” *Accenet.org*. [Online]. Available: https://accenet.org/about/Pages/StudentPaperCompetition.aspx. [Accessed: 11-Jan-2024].