UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

Report No. 3715 Revised

MEMORANDUM

To: Executive Committee of Faculty Council (February 1, 2022)
Faculty Council (February 18, 2022)

From: Professor Dionne Aleman
Associate Dean, Cross-Disciplinary Programs

Date: January 17, 2022; revised February 4, 2022

Re: **Closure of Minor in Biomedical Engineering and Modifications to Minor in Bioengineering**

REPORT CLASSIFICATION

This is a major policy matter that will be considered by the Executive Committee for endorsing and forwarding to Faculty Council for vote as a regular motion (requiring a simple majority of members present and voting to carry).

BACKGROUND

The overlap between the Minor in Bioengineering and the Minor in Biomedical Engineering has caused challenges since they were created in 2006 and 2014 respectively, as students participating in these minors often take similar classes and have similar learning outcomes. In addition, students enrolled in the Biomedical Engineering minor have a lower level of completion than those in the Bioengineering minor.

It is therefore proposed that the Minor in Biomedical Engineering be closed and its requirements and courses be integrated into the Minor in Bioengineering. It is further proposed that the Minor in Bioengineering be modified to include a requirement for a laboratory or hands-on experience, and outline optional pathways and themes for students to focus their electives. The Biomedical Engineering pathway outlines themes on molecular engineering, cell and tissue engineering and clinical engineering. The Bioprocess Engineering pathway outlines themes on biomolecular and microbial engineering, and bioprocess engineering.

PROCESS AND CONSULTATION

The proposed changes have been discussed by and/or received feedback from the IBME Undergraduate Curriculum Committee, Advisory Committee and faculty; the Cross-Disciplinary Programs Office; the Department of Chemical Engineering & Applied Chemistry; the Edward S. Rogers Sr. Department of Electrical & Computer Engineering; students currently enrolled in the two minors

and in CHE353, CHE354 and BME331 (the foundational courses of both minors); the FASE Undergraduate Curriculum Committee; and department chairs and the director of Engineering Science.

RECOMMENDATIONS FOR COUNCIL

THAT the Minor in Biomedical Engineering be closed and its requirements and courses be integrated into the Minor in Bioengineering, as described in Report 3715 Revised. Administrative suspension of enrolment in the program will be effective April 30, 2022 and full closure of the minor will be effective June 30, 2026.

THAT the Minor in Bioengineering be modified to include a laboratory or hands-on course requirement and optional pathways and themes, as described in Report 3715 Revised. Administrative suspension of enrolment in current program requirements will be effective April 30, 2022 and, for students newly enrolled in the minor, new program requirements will be effective May 1, 2022.

University of Toronto
Major Modification Proposal

Modifications to Freestanding Minors Where There is No Existing Specialist or Major

Programs being modified:	Minor in Bioengineering & Minor in Biomedical Engineering
Proposed major modification:	Minor in Bioengineering: • Modify to integrate Biomedical Engineering courses and requirements • Organize courses into two main pathways, including (1) Biomedical Engineering, and (2) Bioprocess Engineering Minor in Biomedical Engineering: • Close as a result of this minor being merged with the Bioengineering minor
Department/unit (if applicable):	Cross-Disciplinary Programs Office (CDPO)
Faculty/academic division:	Faculty of Applied Science and Engineering (FASE)
Dean's Office contact:	Caroline Ziegler, Faculty Governance & Programs Officer (governance.fase@utoronto.ca)
Proponent:	Prof. Dionne Aleman, Associate Dean, Cross-Disciplinary Programs (aleman.mie@utoronto.ca) Prof. Warren Chan, Director, Institute of Biomedical Engineering (warren.chan@utoronto.ca) Prof. Emma Master, Chemical Engineering and Applied Chemistry (emma.master@utoronto.ca)
Version Date:	February 4, 2022

1. Summary

The Faculty of Applied Science and Engineering's (FASE) Minor in Bioengineering was originally created in 2006 and aside from some elective additions, has retained the same structure as when it was created. The Minor in Biomedical Engineering was launched in 2014 as a specialized sub-set of courses that provided an ideal background for the newly created Biomedical MEng program. The overlap between these two minors, and the specificity of the course requirements for the Minor in Biomedical Engineering, has caused challenges over the years.

It is proposed to merge the courses of the Minor in Biomedical Engineering into the Minor in Bioengineering, and close the Minor in Biomedical Engineering. The program requirements of the updated Bioengineering minor will be restructured and it will add a requirement for a lab course, or bio-related capstone/thesis experience to ensure students get a hands-on component in the minor. The calendar listing for the minor will also include recommendations for pathways to help students navigate the range of electives available. The proposal also takes the opportunity to formally articiulate the learning outcomes of the minor.

2. Effective Date

Minor in Bioengineering:

- Administrative suspension of enrolment in current program requirements: April 30, 2022
- New program requirements effective May 1, 2022 for students newly enrolled in the minor

Minor in Biomedical Engineering:

- Administrative suspension of enrolment in the program: April 30, 2022
- Closure of minor with full effect: June 30, 2026

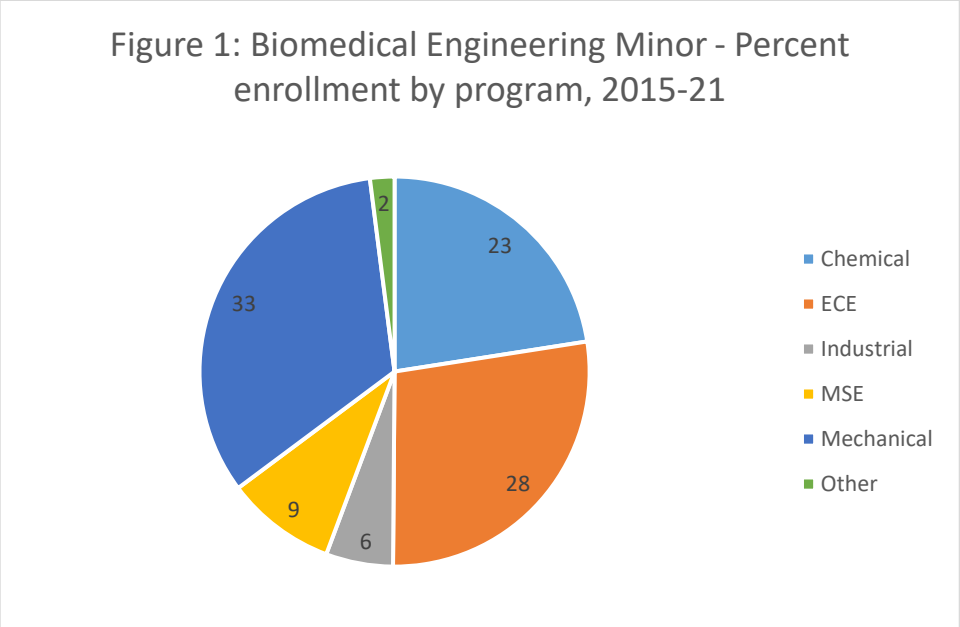
Students enrolled in either program prior to May 1, 2022 will be allowed to complete the old requirements of either minor or switch to the new Bioengineering minor requirements.

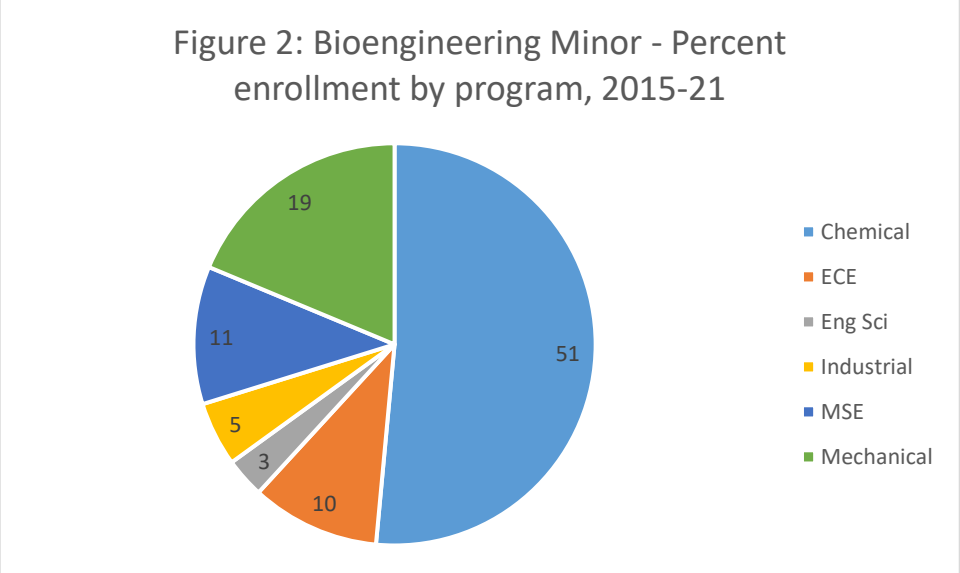
3. Academic Rationale

The Bioengineering minor, introduced in 2006, was the first ever minor in FASE and it was intended for engineering undergraduates interested in learning more about biology and its application to engineering. The term 'bioengineering' is very broad, referring to all areas where engineering and biology intersect. By contrast, the Biomedical Engineering (BME) minor, launched in 2014, is more specific and was designed for those specifically wanting to apply their engineering knowledge to applications in the health care sector. Although the Biomedical Engineering minor is currently a separate minor, there is significant overlap between the two; in their current structures, students that participate in these minors often take similar classes and have similar learning outcomes. As a result, continuing to have two separate minors is redundant and may be confusing to students. Originally there was also a co-curricular Mentorship Program and a seminar series associated with the BME minor which have since been discontinued by the Institute of Biomedical Engineering (IBME).

Students in the minors come from a variety of programs, but primarily from Chemical, ECE and Mechanical Engineering (Figure 1 and 2). Note that some programs (Civil, Mineral, Industrial), do not have a path to completing the minors without taking on considerable extra courses. A small number of students in those programs – particularly those who might be considering applying for med schools in the future – start off in one of the programs, but usually drop it by 3rd or 4th year.

Engineering Science students are not eligible to enroll in the BME minor, but can enroll in Bioengineering, so long as they are not in the Biomedical Systems major.





In its current state, the Biomedical Engineering minor has been struggling with low completion rates (Table 1). Although enrollment numbers have been high and have increased since the program's initial introduction, many students who sign up for the program do not successfully complete the program.

From 2014 to 2021, (7 academic years), 136 students enrolled in the Biomedical Engineering minor program but only 52 students have successfully completed the program. In contrast, during the same period, the Bioengineering minor saw an enrolment of 341 and 265 completions. Annecdotally, the primary reason given for abandoning or switching out of the BME minor was the timetable challenges of fitting the specific, lab intensive courses. Of the 84 students who dropped the Biomedical Engineering minor over this period, 31 (from CHE, MSE

and MEC) switched to the to the more flexible Bioengineering minor, and of those students who switched, 27 have completed or are still actively enrolled in this minor. The Institute of Biomedical Engineering had wanted to add more courses and restructure the Biomedical Engineering minor to increase program flexibility, thereby hopefully improving program completion. However, restructuring the minor to accomplish this has been difficult because of its high similarity to the Bioengineering minor. The key differentiator between the two had been the very focused subset of courses for the Biomedical Engineering Minor. Adding courses would have blurred this distinction.

Table 1: Students graduating with completed minor

	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	Total
BME								
Chemical	1	4	1	4	2	0	3	15
ECE	0	0	1	3	5	12	1	22
MSE	0	0	0	1	0	0	0	1
Mechanical	0	0	1	3	5	1	4	14
Total								52
BIO								
Chemical	8	14	17	29	24	24	33	149
ECE	4	11	6	1	2	0	1	25
Eng Sci	2	0	1	0	0	2	1	6
Industrial	3	1	0	2	1	0	0	7
MSE	3	3	4	5	6	2	5	28
Mechanical	9	5	8	2	8	7	11	50
Total								265

In contrast, the Bioengineering minor is broadly accessible, including a wide variety of courses, but lacks any required exposure to a laboratory component beyond the 12.8P in BME331 or CHE354. The proposed changes are expected to increase the number of students who complete a hands-on component in the minor (e.g., a bio-related capstone/thesis experience), providing practical experiences that help more students convert ideas into real-world applications. The calendar listing for the Bioengineering minor will also include recommendations for pathways to help students navigate the range of electives available.

Given these points, integrating the two minors into a single minor is much more feasible and sensible. Merging the two ultimately allows students to derive full benefit of all the course options rather than trying to divide up courses between minors to make them distinct from each other. It will also avoid confusion among students between two programs that appear very similar. The possibility of a merger has been discussed among core members of both programs and support for this change is very strong.

4. Description of the Proposed Major Modification(s)

We propose the closure of the Biomedical Engineering minor and merger of its requirements and courses into the Bioengineering minor. The single resulting program would be named Bioengineering because the Bioengineering name is broader. Thus, Bioengineering would include Biomedical Engineering. While the Cross-Disciplinary Programs Office (CDPO) will manage the overall activities (e.g., enrollment, tracking completions, calendar, etc.), IBME and CHE will be the initial lead units from September 2022 to August 2024, working in collaboration with other partner units (ECE, MSE, MIE, CIV) in advising students, curriculum design, and management of courses and activities. Co-leadership will ensure a smooth transition of the program as it goes through this merger. Beginning September 2024, BME will be the lead unit and an advisor appointed by CHE (or other unit as appropriate) will remain on to provide vital perspectives and input as it pertains to the Bioprocess pathway.

We propose to recommend (but do not require) that students structure their minor course selections around two pathways in this program:

(1) Biomedical Engineering;
(2) Bioprocess Engineering

These two pathways encapsulate the major learning concepts of the bioengineering field and provide a depth of knowledge relating to molecular and cell scale engineering, manufacturing of biosystems, biochemicals and devices, and the translation of technologies for environmental sustainability and patient care.

Under this restructured program, students will be able to:

- Understand how bioengineering concepts can be applied to address grand challenges facing human and environmental health.
- Understand the relevance of biological systems to the discovery of new medicines, development of sustainable processes, increased food security, and generation of renewable fuels and chemicals.
- Gain greater insights into leading edge approaches used to model and engineer biomolecular and cellular processes.
- Gain hands-on experience with analytical and molecular bio-techniques, solving practical bioengineering problems.

Program Requirements:

Enrollment Requirements: The Bioengineering minor is open to all undergraduate students except for those enrolled in Engineering Science's major in Biomedical Systems Engineering.

General Program Requirements for a Minor: 3.0 full course equivalents (FCE), where no more than 0.5 credits can be a core course in the student's degree program. Departmental capstone and thesis courses are exempt from the core course credit limit.

Completion Requirements:

1. CHE353H1F: Engineering Biology or BME205H1S (for Engineering Science students) (0.5 FCE)

2. Choose at least 1 course (0.5 FCE):
   BME412H1F: Intro to Biomolecular Engineering (recommended for *Biomedical Engineering pathway*)
   BME455H1F: Cellular and Molecular Bioengineering II* (recommended for *both pathways*)
   BME331H1S: Physiological Control Systems (recommended for *Biomedical Engineering pathway*)
   CHE354H1S: Cell and Molecular Biology (recommended for *Bioprocess Engineering pathway*)
   * In order to take BME455 students must complete CHE354 as a pre-requisite.

   Although students are required to only complete 1 out the 4 courses listed above, it is highly recommended to complete 2 of the above courses if scheduling permits.

3. Choose at least 1 course (0.5-1.0 FCE):
   BME498Y1Y: Biomedical Engineering Capstone Design**
   Departmental Thesis (requires approval of Minor Director from BME (Biomedical pathway) or CHE (Bioprocess Pathway))**
   BME440H1F: Biomedical Engineering Technology and Investigation
   CHE450H1F: Bioprocess Technology and Design
   ** Students wishing to register in BME498Y1Y, must obtain approval from the Biomedical Engineering Undergraduate & Graduate Student Office. Some Departments have agreed to accept BME498Y1Y in place of their program's capstone course (existing agreement for ChemE, ECE, MSE, Mech. Alternatively, students who wish to count their departmental thesis or capstone design project towards the Bioengineering minor will be assessed on a case-by-case basis as is currently the case with Bioengineering and other minors.

4. Choose up to 3 courses as needed to bring the total to 3.0 FCE:
   Students may choose any of the below courses but those wishing to concentrate on a particular pathway are recommended to choose courses that fit within that pathway. Within each pathway, students may optionally choose to further focus on a particular theme by taking the recommended courses within that theme.

   1. Biomedical Engineering pathway.
   Courses relevant to the Biomedical Engineering pathway are further grouped into three themes: Molecular engineering, Cell and Tissue engineering, and Clinical engineering:

   Molecular engineering theme:
   BME412H1F: Introduction to Biomolecular Engineering
   BME440H1F: Biomedical Engineering Technology and Investigation
   BME595H1F: Medical Imaging
   CHE475H1S: Biocomposites: Mechanics and Bioinspiration
   ECE448H1S: Biocomputation
   MSE343H1F: Biomaterials

MSE440H1F: Biomaterial Processing and Properties

Cell and Tissue engineering theme:
BME350H1F: Biomedical Systems Engineering I: Organ Systems
BME395H1F: Biomedical Systems Engineering II: Cells and Tissues
BME455H1F: Cellular and Molecular Bioengineering II
MIE439H1F: Cell & Tissue Mechanics
MIE458H1F: Biofluid Mechanics
MIE520H1F: Biotransport Phenomena

Clinical engineering theme:
BME330H1S: Patents in Biology and Medical Devices
BME331H1S: Physiological Control Systems
BME445H1F: Neural Bioelectricity
BME530H1S: Human Whole-Body Biomechanics
ECE446H1F: Sensory Communications

2. Bioprocess Engineering pathway.
Courses relevant to the Bioprocess Engineering pathway are further grouped into two themes: Biomolecular and microbial engineering, and Biomanufacturing:

Biomolecular and Microbial engineering theme:
CHE354H1S: Cellular and Molecular Biology
ECE448H1S: Biocomputation
BCH441HF: Bioinformatics
CHE471H1S: Modeling in Biological and Chemical Systems
BCB420H1S: Computational Systems Biology
CHE4XXH1F: Synthetic Biology

Biomanufacturing theme:
CHE354H1S: Cellular and Molecular Biology
BME330H1S: Patents in Biology and Medical Devices
CHE450F1F: Bioprocess Technology and Design
CHE462H1S: Food Engineering
CHE475H1S: Biocomposites: Mechanics and Bioinspiration
CHE471H1S: Modeling in Biological and Chemical Systems
CHE564H1S: Pulp and Paper Processes
CIV342H1F: Water and Wastewater Treatment Processes
CIV541H1S: Environmental Biotechnology
MGY377H1F: Microbiology I: Bacteria
MSE343H1F: Biomaterials
MIE520H1F: Biotransport Phenomena

3. Additional Elective courses:
Courses related to Bioengineering, outside of the defined pathways above:
CHE416H1S: Chemical Engineering in Human Health

CHM456H1S: Organic Materials Chemistry
ECE331H1F: Analog Electronics
ECE335H1F: Introduction to Electronic Devices
ECE431H1F: Digital Signal Processing
ECE516H1F: Intelligent Image Processing
FOR308H1F: Discovering Wood and its Role in Societal Development *(HSS Elective)*
FOR421H1F: Green Urban Infrastructure: Suitable City Forests
FOR424H1S: Innovation and Manufacturing of Sustainable Materials
FOR425H1S: Bioenergy and Biorefinery Technology
HMB201H1S: Introduction to Genes, Genetics & Biotechnology
HMB265H1F: General & Human Genetics
HPS318H1F: History of Medicine I *(HSS Elective)*
HPS319H1S: History of Medicine II *(HSS Elective)*
IMM250H1F/S: The Immune System & Infectious Disease
MIE242H1F: Psychology for Engineers
MIE343H1F: Industrial Ergonomics and the Workplace
MIE523H1F: Engineering Psychology and Human Performance
MIE561H1S: Healthcare Systems
PCL201H1S: Introduction to Pharmacology and Pharmacokinetic Principles
PCL302H1S: Introduction to Pharmacology: Pharmadynamic Principles
PHL281H1S: Bioethics *(HSS Elective)*
PSL300H1F: Human Physiology I

5. Impact of the Change on Students

Currently, the Biomedical Engineering minor has a steadily high level of enrollment. Despite this, program completion is low. The enrollment and completion trends for the last few years are as follows:

Year	Enrollment		Completion	
	BME	BioEng	BME	BioEng
2014-15	26	41	1	29
2015-16	44	54	4	34
2016-17	72	57	3	36
2017-18	86	79	11	39
2018-19	77	45	12	41
2019-20	50	59	13	35
2020-21	46	71	8	51

New enrollments in the current Bioengineering and Biomedical Engineering minors will be suspended as of April 30, 2022. Students enrolled at that time in either minor will be given the option of completing the current requirements or changing to the new Bioengineering requirements. Given the way the minor is structured, many courses in the Biomedical Engineering

minor are also part of the Bioengineering minor and therefore students who want to switch will be able to do so easily.
All new enrollment in the Bioengineering minor after April 30, 2022 will follow the modified requirements.

The Cross-Disciplinary Programs Office will offer robust advising to ensure that students are aware of their options and able to complete the new program requirements if they choose the updated Bioengineering minor.

6. Consultation

The Biomedical Engineering minor was first discussed by the IBME undergraduate curriculum committee May 15, 2019. In a subsequent meeting on June 17, 2019 the committee agreed that a restructuring of the minor was needed. The committee discussed that changes should match what was discussed for Engineering Science's Biomedical Systems Engineering major. This included aligning courses with the research streams of the Institute. A draft of the initial restructuring proposal was developed following these discussions with the IBME undergraduate curriculum committee. The Associate Dean and the Assistant Director of the Cross-Disciplinary Programs Office were also consulted. Additionally, the proposed changes were discussed with IBME faculty at a faculty meeting on November 18, 2020. Faculty were supportive of changing the minor.

Given the large similarity between the Biomedical Engineering and Bioengineering minors, the Director of the Bioengineering minor was added to the discussion in January 2021 to discuss the Bioengineering minor in light of the proposed restructure of the Biomedical Engineering minor. After initial discussions, consensus was reached that merging the two minors would make the most sense and preliminary details were discussed in a meeting on April 22, 2021. Following this meeting, the IBME advisory committee was consulted along with Prof. Paul Santerre, who initiated the current BME minor, and Prof. Dawn Kilkenny, who oversaw the minor as Associate Director, Undergraduate at the Institute through June 2019. There was support for the merge and renaming the merged program the "Minor in Bioengineering". Preliminary discussions between the Director of the Bioengineering Minor and the Chair of Chemical Engineering, considered the original informal "home" of the Bioengineering Minor were also positive. Details regarding the proposed merged program were drafted and the program requirements outlined. It was agreed that the merged program would still offer the courses previously offered in the current Bioengineering minor but that the requirements would be restructured to include additional biomedical engineering courses and include a practical requirement that would benefit students enrolled in the existing Bioengineering Minor.

On October 13, 2021 students were consulted regarding the planned merger. Students invited to this meeting included current Bioengineering and Biomedical Engineering minor students and students currently in CHE353 (which could be future minor applicants). Student reps for the FASE Undergraduate Curriculum Committee were also invited. Although turnout was low with 16

students registering for the consultation and 8 who attended, feedback regarding the merger was very highly received. All participants were supportive of the change and thought that it offered more flexibility for students. Students echoed that choosing between the Bioengineering and Biomedical Engineering programs was confusing and that the current Biomedical Engineering minor was very restrictive, especially compared to the Bioengineering minor. Students appreciated the proposal that all previously offered bioengineering courses remained in the proposed structure.

Within IBME, a faculty meeting was held October 14, 2021 to discuss the current merger proposal. IBME faculty members expressed that they were supportive of the change and that it makes a lot of sense to combine the minors. The only major feedback regarding the proposal is that some faculty members want to see the program grow to include more electrical engineering courses and courses focused on entrepreneurship and industrialization.

The merger proposal was presented at the FASE Undergraduate Curriculum Committee on October 29th and was endorsed by the representatives there. The committee comprises curriculum representatives (Associate Chairs, Undergraduate or designates) from each of the departments and divisions.

The merger proposal was then circulated to all department chairs and the EngSci director in advance of the Executive Committee meeting. This spurred additional discussions and consultations within CHE, including with the BioZone leadership and CHE Curriculum Committee. CHE faculty members expressed their support for merging the Bioengineering Minor and Biomedical Minor, however, faculty members wanted to see a greater balance between biomedical engineering and bioprocess engineering elements of the minor. This led to the current proposal, which describes two main pathways within the Bioengineering Minor (i.e., Biomedical Engineering and Bioprocess Engineering), and co-leads (one from IBME and one from CHE) for the first two years of the new Bioengineering Minor, after which time a CHE faculty member (or member of another unit) will remain to guide the development of the Bioprocess pathway. An e-mail consultation with IBME was conducted (Dec 15-22) and no issues with the proposed changes were raised.

Feedback was also received at this time from ECE in support of the merged minor that there was a preference to retain the Biomedical Engineering name rather than Bioengineering. However, given the dual pathways of the merged minor, it is clear the content of the program goes beyond biomedical applications. Upon further consultation in January, it was agreed that a handful of courses on ECE-related topics be added to the course offering, as the current curriculum is heavy on biology and chemistry but scant on fundamental training critical to several areas of bioengineering, including devices, imaging, and machine learning. After consulting with ECE-BME stakeholders, four courses were added to the category of “3. Additional Elective Courses”. Additions to the learning outcomes in Appendix A were also included.

A final consultation with students was conducted on January 10, 2022, and the feedback was positive. A student indicated that they would like to see the pathways or streams included on the transcript notation. While students are free to highlight completion of a pathway or theme informally in a graduate school or job application, there is no plan to include them on transcripts currently.

The updated proposal was endorsed once again by UCC on January 10, 2022.

7. Resources

There will be no changes to the resources available to students regarding faculty complement, space, and libraries. Both IBME and Chemical Engineering have committed to staffing their respective core courses in the merged minor going forward. All elective courses offered previously will continue to be offered and will continue to be administered by their home department or division.

The IBME Undergraduate Program Administrator will continue to assist with course administration for BME courses and advise students on the minor, as they did for the current BME minor. The Cross-Disciplinary Programs Office will continue to oversee the minor administration and admissions and overall student advising. The initial Directorship of the merged minor will include representation from BME (Prof. Warren Chan) and CHE (Prof. Emma Master). The Directors and/or corresponding undergraduate program administrators will consult with appropriate colleagues across FASE as necessary to provide guidance to students and ensure courses within the pathways are consistent and appropriate. This may include identifying informal advisors for each of the pathways.

8. UTQAP Process

The UTQAP pathway is summarized in the table below.

Steps	**Dates**
Development in consultation with IBME, CDPO, Chemical Engineering	May 2019-December 2021
Consultation with Dean's Office (and Vice-Provost, Academic Programs)	October-November 2021
Endorsement of FASE Undergraduate Curriculum Committee	January 10, 2022
Approval of FASE Council	February 18, 2022
Submission to Provost's Office	January 2022
Reported to Provost for inclusion in annual report to AP&P	June 2022
Reported annually by Provost to Ontario Quality Council	July 2022

Appendix A: Proposed Learning Outcomes and Degree Level Expectations

The Faculty of Applied Science & Engineering aims to provide all of its undergraduate students with an education that will encourage them to be leaders in society in developing solutions to its most pressing problems. In order to achieve this, each graduate will have achieved the Degree-Level Expectations for the BASc described in Appendix B.

Engineering minors and certificates are designed to recognize students for focusing their degree-program electives in a particular area of study. They are optional structures above and beyond a student's degree requirements and are therefore enhancements to existing rigorous degree-level expectations for engineering programs.

Learning outcomes for the original Biomedical Engineering and Bioengineering minors are not available as, when these minors were first introduced, the creation of learning outcomes was not required. Below are the learning outcomes for the modified Bioengineering Minor program.

Degree-Level Expectations for the Bachelor of Applied Science (BASc)	Additional Program Learning Outcomes for the Modified Bioengineering Minor	How the Modified Bioengineering Minor's Design/Structure Supports the Degree Level Expectations
Depth and Breadth of Knowledge Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	Develop a basic understanding of how to apply engineering principles to biological systems.	Learners will take the required course CHE353. This course provides an overview of how to apply engineering techniques to address biology and health problems. The learners will take specialized courses in different areas of bioengineering for added depth and knowledge.
Knowledge of Methodologies Demonstrated competence in understanding the methods of engineering design.	Depending on their course selections, students will gain a theoretical understanding and practical competence in topics such as: measuring and analyzing biological signals, designing devices, designing biocompatible materials, applying fluid dynamics to flow phenomena, understanding tissue mechanics, kinetics of biological and biochemical processes, mass balances of biological and biochemical processes, DNA and protein manipulations.	We have developed both lab and capstone courses for the minor program. These courses teach practical skillsets applicable to different areas of bioengineering research, translation and development.

Degree-Level Expectations for the Bachelor of Applied Science (BASc)	Additional Program Learning Outcomes for the Modified Bioengineering Minor	How the Modified Bioengineering Minor's Design/Structure Supports the Degree Level Expectations
Application of Knowledge Demonstrated competence in applying science and mathematics to solve problems.	Depending on their course selections, students will apply their knowledge in areas such as engineering molecular devices and systems, building imaging platforms for diagnostics and intervention-guidance, building cell and tissue therapies, building engineering devices for treating or rehabilitating patients, synthesizing materials for drug delivery and therapy, applying machine learning to bioengineering problems, applying microbial processes in biomanufacturing, carbon capture and bioremediation.	We design a series of courses that covers various aspects of bioengineering. In parallel, we offer lab/capstone courses that allows learners to apply their knowledge. We will also encourage learners to do thesis projects, which provides students independent research experience to apply their knowledge.
Communication Skills Demonstrated ability to communicate information, arguments, and analysis accurately and reliably, orally and in writing, to specialist and non-specialist audiences.	Competence in data visualization and working in collaborative research teams, communicating results and ideas, and ability to write and explain bioengineering concepts.	Courses will contain writing assignments and presentation of ideas/concepts. The addition of these tasks will teach students communication skills. Additionally, writing and presentation are strong part of the practical courses.
Awareness of Limits of Knowledge Demonstrated knowledge and appreciation of the uncertainties, ambiguities and limitations of knowledge in the specific field.	Competencies in understanding the limits of bioengineering concepts and practical utility of resulting technologies.	Our practical courses plus thesis activities will teach learners limitations with bioengineering concepts. Our practical courses will teach the limitations of technologies. Our teachers will address these limitations through presentation, oral communication, and discussions with learners.
Autonomy and Professional Capacity Development of an awareness and understanding of professional practice; a demonstrated ability to work in teams and	Competencies with working on projects. This competency includes planning and executing projects, evaluation of progress, and addressing alternatives. It also includes a clear understanding of how one contributes to results.	Learning autonomy and professional capacity will occur through practical experience. Capstone courses will be provided for students to work in team and for clients. Mini projects in lab courses with teach students autonomy and project limitations.

Degree-Level Expectations for the Bachelor of Applied Science (BASc)	Additional Program Learning Outcomes for the Modified Bioengineering Minor	How the Modified Bioengineering Minor's Design/Structure Supports the Degree Level Expectations
accept responsibility for one's own work and contributions.		
Other Degree Level Expectations Developed competencies in quantitative reasoning (i.e., the ability to identify, assemble and interpret quantitative information; make and test hypotheses) and in information literacy.	We expect students to understand quantitative reasoning, decision making, and evaluation of information.	Our courses will provide problem sets to evaluate concepts and ideas. Our practical classes teach skillsets to evaluate problems and to make use information for effective decision making.

Appendix B: Degree Level Expectations for Graduates Receiving the Degree of Bachelor of Applied Science

Faculty of Applied Science and Engineering
University of Toronto

1 Degree Learning Objectives and Requirements

1.1 Overall Learning Objectives

The Faculty of Applied Science and Engineering aims to provide all of its undergraduate students with an education that will allow them to be leaders in society in developing solutions to its most pressing problems. Our graduates will be able and inspired to:

- be leading practitioners of engineering and engineering design
- be known for their technical literacy as well as their knowledge of mathematics and the basic sciences and the role of technology in society
- be able to formulate and solve problems in complex systems independently and in teams
- pursue independent lifelong learning within their field of study and more broadly
- be prepared for careers, including graduate programs, that build upon their advanced technical knowledge
- participate meaningfully as leaders in society

In order to achieve this, each graduate will have achieved the following general learning objectives:

a. Depth of knowledge that cultivates critical understanding and intellectual rigour in at least one engineering discipline.
b. Competencies in learning and applying knowledge to solve problems facing society and that are fundamental to responsible and effective participation in the workplace, in the community, in scholarly activity, and in personal life:
    i. Critical and Creative Thinking
    ii. Oral and Written Communication
    iii. Quantitative Reasoning
    iv. Teamwork
    v. Information Literacy
    vi. Ethical Thinking and Decision-Making
c. Breadth of knowledge across mathematics, basic sciences, engineering sciences, engineering economics and engineering design that cut across the engineering disciplines and across a range of nontechnical areas including the humanities and social sciences and an awareness of the impact of technology on society.
d. Integration of skills and knowledge developed in a student's course of study through a capstone experience in the upper years.

1.2 Requirements to Graduate

In order to graduate with a B.A.Sc. degree, each student in the Faculty of Applied Science and Engineering will have completed a full undergraduate program as outlined in the Faculty Calendar within nine calendar years of first registration, exclusive of mandatory absences from his/her program. Current programs include Chemical, Civil, Computer, Electrical, Industrial, Mineral, Materials and Mechanical Engineering.

The practice of engineering is regulated, by statute, in all Canadian provinces and territories. To become a Professional Engineer, an individual must satisfy the requirements of the licensing bodies.

These requirements include a degree from an accredited program, successful completion of a professional practice examination in engineering law and ethics, and suitable experience. At present, all programs in the Faculty of Applied Science and Engineering are accredited and evaluated regularly by the Canadian Engineering Accreditation Board (CEAB) of the Canadian Council of Professional Engineers. Therefore, graduation from the Faculty may lead to registration in the provincial Associations of Professional Engineers, in accordance with individual policies. No student will be permitted to graduate who does not meet these requirements.

The criteria set out by the CEAB are designed to ensure that each graduate has a foundation in Mathematics and Basic Sciences, a broad preparation in Engineering Sciences and Engineering Design and an exposure to non-technical subjects (Complementary Studies) that complement the technical aspects of the curriculum. Basic Sciences must include physics and chemistry and also may include elements of life sciences and earth sciences; they impart an understanding of natural phenomena. Engineering Sciences normally involve mathematics and Basic Sciences but carry knowledge further to creative applications. Complementary studies include the humanities, social sciences, arts, management, engineering economics and communication skills.

Each program in the Faculty consists of a technical component and complementary studies component. The curriculum for students in their early years forms a basis in the fundamental subjects prior to subsequent specialization in the various engineering disciplines. Students are able to choose from a range of technical electives in their senior years. In the senior years, all programs contain a Capstone experience through a design project, which integrates their skills and knowledge and provides students with the opportunity to carry out original work in their chosen fields of study.

There are a set of common requirements, described below, that cut across all programs in the following categories: Coursework; Promotion; English Proficiency; and Practical Experience. In this context, a course is defined as one half-course equivalent, which may consist of a half course (“S”, “F” or “H”) or half of a full year “Y” course.

1. Coursework: Each program will have courses that provide the following:
    a. Complementary Studies Electives
    b. A basic knowledge of Engineering Economics

c. Technical Electives

d. Courses with substantial design content in Years 1, 2 and/or 3

e. Capstone course(s) in Years 3 and/or 4 with strong integrative, design and independent work elements

f. Across all four years, programs will provide sufficient opportunities for the development of professional awareness and practice.

2. Promotion: All undergraduate programs will consist of eight Fall and Winter Sessions taken in order.

    a. To gain credit for a session a student must:

        i. satisfy the academic regulations to proceed to the succeeding session as described in the calendar and

        ii. not be subsequently required to repeat the session for which credit is to be gained, and

        iii. achieve a course mark of 50% or greater in every course taken as part of the academic load in a session, and

        iv. not have any outstanding designations of 'standing deferred', 'incomplete' or 'No Grade Available' for any course in any session.

    b. To be eligible to graduate, each student must attain a weighted Session Average of 60% or greater in the final session of their program. Any student who does not achieve a weighted Session Average of 60% in their final session (4W), but has attained a weighted Session Average that allows them to proceed to the next session on probation, shall repeat the final session and achieve a weighted Session Average of 60% or greater to graduate.

3. English Proficiency: Each student must show an ability to write English coherently and correctly. Every student will also take at least one course that includes a written communication component within their curriculum. Satisfactory completion of the course or courses is required for graduation.

4. Practical Experience: The Faculty requires that all students complete a minimum of 600 hours of practical work before graduation.

2 Degree Level Expectations for the Bachelor of Applied Science

2.1 Depth and Breadth of Knowledge

The Faculty ensures that a student has mastered a body of knowledge with appropriate depth by requiring that each student completes the requirements of one of the degree Programs of Study (POSt) as described in the Faculty Calendar. The curriculum for students in First Year forms a common basis in the fundamental subjects, including the natural sciences and mathematics, prior to a subsequent specialization in the various engineering disciplines. Each program consists of a technical component and a complementary studies component.

Critical analysis and thinking and analytical skills are emphasized through the student's exposure to an increasingly sophisticated understanding of their program of study. Specialization within the discipline is developed through technical electives taken in the 3rd and 4th years of study. A detailed knowledge of and experience in design is ensured through the Design Course requirements, beginning with courses in the first three years as well as the Capstone course(s) in each program. Opportunity to further develop these skills is provided through a research thesis that is available in most POSts.

The Faculty assures that students have breadth of knowledge in a number of ways. Breadth across engineering is assured through a First Year of study that prepares a student for any of the programs of study. Breadth beyond engineering is developed through the Complementary Studies Electives as well as the Engineering Economics requirement.

2.2 Knowledge of Methodologies

Every POSt has requirements which demonstrates a student's understanding of the methods of engineering design. Students in all engineering programs must successfully complete courses with substantial design in their first three years and a Capstone design course in their senior years. These courses require students to evaluate the appropriateness of various approaches to analyze and solve the design problem and also to devise and sustain arguments for their design. In most POSts, students have the opportunity to participate in a research thesis course that familiarizes them with the specific methodologies currently in use in the development of knowledge in their discipline.

2.3 Application of Knowledge

The application of science and mathematics to solve problems is fundamental to all programs in Engineering and therefore is required in many of the courses within all POSt. A minimum level of instruction in Engineering Science and Engineering Design is required, both of which directly involve the application of knowledge.

2.4 Communication Skills

The Faculty requires students to communicate information, arguments and analysis accurately and reliably, orally and in writing, to specialist and non-specialists audiences. The requirement for courses with substantial engineering design that are required across all programs require a series of technical reports and presentations with direct involvement with our Engineering Communication Program. In addition, our Capstone Design Courses and research theses all involve a written report and most involve oral presentations. The course requirements for instruction in Complementary Studies also adds to the education our students receive in communication skills. Also, the English Proficiency requirement insures a minimum level of writing ability for all graduates.

2.5 Awareness of Limits of Knowledge

Each POSt develops, through a sequence of courses starting at the 100-series or 200-series and culminating at the 300-series or 400-series or 500-series of courses, an understanding of a discipline as it is currently appreciated by educators who are at the same time involved in

original scholarship in the subject area. The course content at the upper series level is designed, in part, to provide students with an appreciation of the uncertainties, ambiguities and limitations of knowledge in the specific area.

2.6 Autonomy and Professional Capacity

The development of an awareness and understanding of professional practice is required for all POSt. The required design courses require students to work in teams and also accept responsibility for their own contributions. Students are required to make their own decisions for their own learning through selection of their technical and nontechnical electives. Finally, in completing their course requirements, the Faculty expects strict adherence by students to the Code of Behaviour on Academic Matters, which requires students to not tolerate or encourage the creation of an environment of cheating, misrepresentation or unfairness.

2.7 Other Degree Level Expectations

The Faculty requires all students to have developed competency in several areas of learning and applying knowledge not identified explicitly in the previous sections. In particular, the Faculty requires students to have developed competencies in quantitative reasoning and in information literacy.

Quantitative reasoning is considered the ability to identify, assemble and interpret quantitative information and make and test hypotheses based on such data. Development of this competency is an explicit part of all POSts offered by the Faculty.

The Faculty requires all students to develop an advanced understanding of how to obtain information, manipulate and evaluate it and bring diverse sources together to develop a comprehensive understanding of specific issues, solve problems or apply the scientific method to create further knowledge in the discipline. These advanced information literacy skills are developed through the studies in their concentration(s) and are demonstrated in the advanced courses required in each POSt.

Appendix C: Current Calendar Copy with Changes Tracked or Highlighted

The Undergraduate Bioengineering Minor is a collaborative effort across the Faculty of Applied Science and Engineering and is open to engineering students interested in learning more about biology and its breadth of application to engineering. Our definition of bioengineering is broad, reaching to all areas at the interface of engineering and biology. The minor provides in-depth knowledge from molecular and cell scale engineering, manufacturing of biosystems and devices, to translation of technologies ranging from sustainable energy and renewable bioproducts to patient care. All undergraduate engineering students except students in Engineering Science's Biomedical Systems Engineering major are eligible to participate in this minor course of study.

Further information on the minor can be found at www.minors.engineering.utoronto.ca.

Requirements for the Minor in Bioengineering

The requirements for a Bioengineering Minor in the Faculty of Applied Science and Engineering are the successful completion of the following courses:

1. CHE353H1 OR BME205H1** (0.5 FCE)

2. Choose at least 1 course (0.5 FCE):
    a. BME412H1, recommended for Biomedical Engineering pathway
    b. BME455H1, recommended for both pathways
    c. BME331H1, recommended for Biomedical Engineering pathway
    d. CHE354H1, recommended for Bioprocess Engineering pathway

   Although students are required to only complete 1 out of the 4 courses listed above, it is highly recommended to complete 2 of the above courses if scheduling permits.

3. Choose at least 1 course (0.5 FCE):
    a. BME498Y1 #
    b. Departmental Thesis (requires approval of Minor Director from BME (Biomedical pathway) or CHE (Bioprocess Pathway))#
    c. BME440H1
    d. CHE450H1

4. Choose up to three electives as needed to bring the total to 3.0 FCE.
   Students may choose any of the below courses but those wishing to concentrate on a particular pathway are recommended to choose courses that fit within that category.

   Biomedical Engineering pathway:
   Courses relevant to the Biomedical Engineering pathway are further grouped into three themes: Molecular engineering, Cell and Tissue Engineering and Clinical Engineering:

a. *Molecular theme*: BME412H1X, BME440H1, BME595H1, CHE475H1, ECE448H1, MSE343H1, MSE440H1
b. *Cell & Tissue theme*: BME350H1, BME395H1, BME455H1, MIE439H1, MIE458H1, MIE520H1
c. *Clinical theme*: BME330H1, BME331H1, BME445H1, BME530H1, ECE446H1

Bioprocess Engineering pathway:
Courses relevant to the Bioprocess Engineering pathway are further grouped into two themes: Biomolecular and microbial engineering, and Biomanufacturing:

a. *Biomolecular and Microbial engineering theme*: CHE354H1, ECE448H1, BCH441H1, CHE471H1, BCB420H1, CHE4XXH1
b. *Biomanufacturing pathway theme*: CHE354H1, BME330H1, CHE450H1, CHE462H1, CHE475H1, CHE471H1, CHE564H1, CIV342H1, CIV541H1, MGY377H1, MSE343H1, MIE520H1

Additional elective courses: CHE416H1, CHM456H1, ECE331H1, ECE335H1, ECE431H1, ECE516H1, FOR308H1, FOR421H1, FOR424H1, FOR425H1, HMB201H1, HMB265H1, HPS318H1, HPS319H1, IMM250H1, MIE242H1, MIE343H1, MIE523H1, MIE561H1, PCL201H1, PCL302H1, PHL281H1, PSL300H1

**BME205 is only available for enrollment for Engineering Science students
Students wishing to register in BME498Y1Y must obtain approval from the Biomedical Engineering Undergraduate & Graduate Student Office. Some departments have agreed to accept BME498Y1Y in place of their program's capstone course (existing agreement for ChemE, ECE, MSE, ME. Alternatively, students who wish to count their departmental thesis or capstone design project towards the Bioengineering minor will be assessed on a case-by-case basis as is currently the case with Bioengineering and other minors.

		Lect.	Lab.	Tut.	Wgt.
One of:					
CHE353H1: Engineering Biology	F	2	-	2	0.50
BME205H1: Fundamentals of Biomedical Engineering	S	2	1.50	1	0.50
At least one of:					
BME331H1: Physiological Control Systems	S	3	1	1	0.50
BME412H1: Introduction to Biomolecular Engineering	F				
BME455H1: Cellular and Molecular Bioengineering II	F	3	1.50	1	0.50
CHE354H1: Cellular and Molecular Biology	S	3	1	2	0.50
At least one of:					

BME440H1: Biomedical Engineering Technology and Investigation	S	2	4	-	0.50
BME498Y1: Biomedical Engineering Capstone Design	Y				
CHE450H1: Bioprocess Technology and Design	F	3	0.66	1	0.50
Bioengineering-related capstone or thesis with Director's approval	F/S/Y				0.5 or 1.0
As needed to bring credit weight to 3.0:					
BME330H1: Patents in Biology and Medical Devices	S	3	-	-	0.50
BME350H1: Biomedical Systems Engineering I: Organ Systems	F	3	1	2	0.50
BME395H1: Biomedical Systems Engineering II: Cells and Tissues	F	2	1	2	0.50
BME445H1: Neural Bioelectricity	F	3	1.50	1	0.50
BME530H1: Whole-Body Mechanics	S	3	2	-	0.50
BME595H1: Medical Imaging	F	2	3	1	0.50
CHE416H1: Chemical Engineering in Human Health	S	3	-	-	0.50
CHE450H1: Bioprocess Technology and Design	F				
CHE462H1: Food Engineering	S	3	-	1	0.50
CHE471H1: Modelling in Biological and Chemical Systems	S	3	-	1	0.50
CHE475H1: Biocomposites: Mechanics and Bioinspiration	S	3	-	1	0.50
CHE564H1: Pulp and Paper Processes	S	3	-	1	0.50
CIV342H1: Water and Wastewater Treatment Processes	F	3	1	1	0.50
CIV541H1: Environmental Biotechnology	S	3	-	-	0.50
ECE331H1: Analog Electronics	F	3	1.5	1	0.50
ECE335H1: Introduction to Electronic Devices	F	3	-	2	0.50
ECE431H1: Digital Signal Processing	F	3	1.5	1	0.50
ECE446H1: Sensory Communication	F	3	1.50	-	0.50
ECE448H1: Biocomputation	S	3	-	2	0.50
ECE516H1: Intelligent Imaging Processing	F	3	3	-	0.50
FOR308H1: Discovering Wood and its Role in Societal Development	F	3	-	1	0.50
FOR421H1: Green Urban Infrastructure: Sustainable City Forests	F	2	-	-	0.50
FOR424H1: Innovation and Manufacturing of Sustainable Materials	S	2	-	1	0.50

FOR425H1: Bioenergy and Biorefinery Technology	S	2	-	2	0.50
MIE242H1: Psychology For Engineers	F	3	3	-	0.50
MIE343H1: Industrial Ergonomics and the Workplace	F	3	3	-	0.50
MIE439H1: Cell and Tissue Mechanics	F	3	2	-	0.50
MIE458H1: Biofluid Mechanics	F	3	-	1	0.50
MIE520H1: Biotransport Phenomena	F	3	-	1	0.50
MIE523H1: Engineering Psychology and Human Performance	F	3	3	-	0.50
MIE561H1: Healthcare Systems	S	3	-	2	0.50
MSE343H1: Biomaterials	F	3	-	1	0.50
MSE440H1: Biomaterial Processing and Properties	F				
BCB420H1: Computational Systems Biology	S	2	-	2	0.50
BCH441H1: Bioinfomatics	F	2	-	1	0.50
CHM456H1: Organic Materials Chemistry	S	2	-	-	0.50
HMB201H1: Introduction to Fundamental Genetics and its Applications	S	2	-	1	0.50
HMB265H1: General & Human Genetics	F	2	-	1	0.50
HPS318H1: History of Medicine I					
HPS319H1: History of Medicine II	S	-	-	-	0.50
IMM250H1: The Immune System & Infectious Disease	S	-	-	-	0.50
MGY377H1: Microbiology I: Bacteria	F	3	-	-	0.50
PCL201H1: Introduction to Pharmacology and Pharmacokinetic Principles	S	3	-	1	0.50
PCL302H1: Introduction to Pharmacology: Pharmadynamic Principles					
PHL281H1 (formerly PHL281Y1): Bioethics	S	-	-	-	0.50
PSL300H1: Human Physiology I	F	3	-	1	0.50

NOTE:

1. BME205H1, BME350H1 and BME395H1 are only open to Engineering Science Students.