ACKNOWLEDGEMENT

UBC's Point Grey Campus is located on the traditional, ancestral, and unceded territory of the xwməθkwəy̓əm (Musqueam) people. The land it is situated on has always been a place of learning for the Musqueam people, who for millennia have passed on their culture, history, and traditions from one generation to the next on this site.

COURSE INFORMATION

Course Title	Course Code Number	Credit Value
Process Development: Bench to Full Scale	CHBE 411	3

Course Calendar Description

The course introduces students to the tools and techniques that seasoned engineers use to technically evaluate novel upcoming process technologies, to formulate development programs around them, and to build full engineering design packages for them. The course builds around the skill-set engineers need to technically and successfully support process start-ups and companies developing new and novel process technologies. Specific topics that are discussed include process technology feasibility evaluations, development of techno-economic analyses for process technologies and their use in the planning and build-up of technology development programs, the use of dimensional analysis and empirical techniques for the scale up of equipment and processes, the design and use of pilot plants in the scale-up and de-risking of process technologies, and the translation of scientific lab and pilot work results into full scale engineering design packages. In short, the steps to technically move a process technology from a lab bench idea to its full commercial implementation.

PREREQUISITES

CHBE 241 (or equivalent)
CHBE 345 (or equivalent)

CONTACTS

Course Instructor(s)	Contact Details	Office Location	Office Hours
Sergio Berretta	Sergio.berretta@ubc.ca	CHBE 431	By appointment

COURSE INSTRUCTOR BIOGRAPHICAL STATEMENT

Sergio Berretta (B.A.Sc., 1995) is a chemical engineer with over 30 years of industrial experience on technology evaluation and de-risking, technology development, process scale-up, and detail engineering design of process technologies. For almost two decades, Sergio worked in the design and commissioning

of large chemical plants worldwide, with projects in four continents. For the last decade, Sergio has been working on the scale-up and de-risking of novel process technologies, including the detail design of pilot plants. He is a past Chief Operating Officer of BC Research and a founding executive of the Carbon Capture and Conversion Institute. He is currently a professor of practice at the University of British Columbia in the department of Chemical and Biological Engineering where he teaches engineering design of chemical and biological processes, assessment of carbon capture/conversion/storage technologies, and process technology evaluation/scale-up/translation. He also remains an active consultant for a number of start-ups in Europe and North America.

https://www.linkedin.com/in/sergioberretta/

COURSE NARRATIVE

Up to now, much has been published on the development and commercialization of technologies, with full university courses dedicated to these areas. The vast majority of these courses cover the business aspects of technology commercialization, such as business plans, market studies, funding strategies, and commercialization proposals. They also address how to integrate these elements into cohesive business commercialization plans.

In contrast, the technical aspects of developing and scaling up a technology—particularly the integrated approach to the technical activities involved—have received far less attention. This is especially true for the development and commercialization of chemical and biological process technologies. In industry, there is a general presumption that scientists or development engineers know, or ought to know, how to technically advance process innovations from the idea phase to commercial introduction. They are expected to integrate the knowledge gained from their various technical university courses to achieve this goal. Unfortunately, few are able to effectively connect the knowledge from their "siloed" university technical courses to understand how to proficiently achieve this goal.

The objective of the course is to introduce the necessary connections in the knowledge students gained through their technical university courses when applied to the formulation and completion of the technical phases of a process development and scale-up project in the area of chemical and biological processes, from the idea phase to the commercial introduction of the technology.

The course is designed for engineering students interested in the development and commercialization of process technologies—a key step in creating new ventures. Students will receive an overarching framework to evaluate the technical viability of process technologies and will be trained in the use of tools and strategies to scale up equipment and processes, as well as to translate research breakthroughs into fully commercialized processes. Through real-world examples, students will learn how to navigate the typical steps involved in developing and scaling up process technologies, including:

- Validating the technical viability of a process concept at the ideation phase

- Preparing techno-economic evaluations of novel process concepts
- Formulating technology development programs
- Scaling up a process from the bench to a pilot plant, then to a demonstration plant, and finally to a full commercial plant
- Designing pilot plants and using them to scale up and de-risk process technologies
- Translating lab and pilot plant results into engineering design packages
- Assessing the roadblocks and benefits of intellectual property strategies in the development of process technologies

The course will be delivered through a combination of lectures and assignments where students will refine their newly acquired skills.

COURSE STRUCTURE

The course is divided into six interwoven modules:

Module 1 – An introduction to process technology scale-up, de-risking and translation of chemical and biological processes

Through this module we will work on:

- Understanding the difference between Research vs Development work
- An introduction to Technology Readiness Levels (TRL) in the chemical and biological technology development area
- An introduction to the typical technical work completed at the different TRLs of a chemical and biological technology development project
- An overview of how chemical and biological engineering skills and knowledge connect with the technical work completed at the different phases of the development of a novel chemical or biological process

Module 2 – Early stage technical feasibility assessment of novel chemical or biological processes

Through this module we will work on:

- Learning how to place a novel chemical or biological concept within the context of a full process
- Generating a first-pass technical feasibility evaluation of novel chemical or biological ideas
- Early stage evaluation of:
  - Economic potential of the idea
  - Effect of product specification requirements
  - Health and Safety consideration issues

    - Review of IP landscape and its effect on novel ideas
- Deciding whether or not a novel concept warrants development work and investment

Module 3 – Formulating a Development Program for a Novel Chemical or Biological Process

Through this module we will work on:

- Completing the foundational work required to build a development program
    - An introduction to Life Cycle Analysis (LCA) and how it relates to the technical evaluation of novel chemical or biological processes
    - An introduction to Techno-Economic Analysis (TEA) and how it relates to the technical evaluation of novel chemical or biological processes
- Formulating a technology development program based on the results of an LCA and TEA analysis
- An introduction to scale-up and its place in the technology development pathway of novel chemical and biological processes

Module 4 – Process scale-up in the Development of Novel Chemical and Biological Processes

Through this module we will work on:

- Selecting the correct scale-up techniques to specific process technologies
- The use of dimensional analysis in the scale-up of chemical and biological processes
- The use of heuristics in the scale-up of chemical and biological processes
- The use of pilot equipment or systems in the scale-up of chemical and biological processes

Module 5 – Translating Development Work Results into Engineering Design Packages

Through this module we will work on:

- An introduction to pre-FEED, FEED, and Detailed Engineering Packages
- Understanding the output of development and scale-up work
- Understanding the input required by design engineers to design and build commercial plants
- Translating development and scale-up work results into a pre-FEED package

Module 6 - An Introduction to Patent Reviews from the Perspective of Development Work

Through this module we will work on:

- Understanding the different IP strategies available to development projects
- Learning how to read patents
- Understanding how patents constraint technology development strategies

As part of CHBE 411, each week you are required to go through the "prep", which mainly includes a reading. There are two 75-minute weekly lectures. The provisions for adapting this to an online learning platform is as follows:

- The 75 minutes lecture will be offered live in-person on campus. Recording of the classes will not be offered, but the lecture slides will be posted.
- Class notes, which make-up the bulk of the weekly readings, will be posted on a weekly basis. Their content covers most of the content of the lectures.

There are two in-class quizzes, a mid-term, and a final exam on this course.

SCHEDULE OF TOPICS

Here is a tentative schedule for the course. If there are any changes to the schedule, you will be notified.

Module	Week	Topics
1	1	• Understanding the difference between Research vs Development work • An introduction to Technology Readiness Levels (TRL) in the chemical and biological technology development area • An introduction to the typical technical work completed at the different TRLs of a chemical and biological technology development project
2	2	• An overview of how chemical and biological engineering skills and knowledge connect with the technical work completed at the different phases of the development of a novel chemical or biological process
	3	• Learning how to place a novel chemical or biological concept within the context of a full process • Generating a first-pass technical feasibility evaluation of novel chemical or biological ideas from an economic potential perspective

	4	• Generating a first-pass technical feasibility evaluation of novel chemical or biological ideas from an economic potential perspective
		  • Health and Safety perspective
		  • Environmental perspective

		• IP perspective • Development decision making process based on the first-pass analysis
3	5	• Completing the foundational work required to build a development program (LCA perspective)
	6	• Completing the foundational work required to build a development program (TEA perspective – part 1)
	7	• Completing the foundational work required to build a development program (TEA perspective – part 2)
	8	• Formulating a technology development program based on the results of an LCA and TEA analysis • An introduction to scale-up and its place in the technology development pathway of novel chemical and biological processes
4	9	• Selecting the correct scale-up techniques to specific process technologies • The use of dimensional analysis in the scale-up of chemical and biological processes
	10	• The use of heuristics in the scale-up of chemical and biological processes • The use of pilot equipment or systems in the scale-up of chemical and biological processes
5	11	• An introduction to pre-FEED*, FEED, and Detailed Engineering Packages • Understanding the output of development and scale-up work
6	12	• Understanding the input required by design engineers to design and build commercial plants • Translating development and scale-up work results into a pre-FEED package • Understanding the different IP strategies available to development projects
	13	• Learning how to read patents • Understanding how patents constraint technology development strategies

* FEED – Front End Engineering Design

LEARNING OUTCOMES

By the end of the course, the students will have the knowledge and skills to:

- Know what is involved when working in research vs development in the area of processes (Module 1)
- Make the connection in the relevant technical knowledge gained through different CHBE technical

courses when applied to completing the typical tasks involved in the development of process technologies (Module 1)

- Know how to technical evaluate early stage novel process ideas using a feasibility assessment approach. (Module 2)
- Prepare Techno-Economic Assessments using mass and energy balances, economic evaluation tools, and sensitivity/uncertainty analysis techniques (Module 3)
- Know how to use the output of LCAs and TEAs studies in the formulation of complete technology development programs for novel chemical and biological processes (Module 3)
- Select the correct scale-up techniques (Module 4)
- Use dimensional analysis and heuristics in the scale-up of equipment and processes (Module 4)
- Translate development and scale-up work results into engineering design packages (Module 5)
- Evaluate different IP strategies, and properly read patents, and use this knowledge to better frame development strategies around chemical and biological processes (Module 6)

LEARNING MATERIALS

No single textbook is assigned to this course. Course notes have been prepared. Additional references are provided in the course notes.

The course notes are proprietary to the course and they are provided to the students for their own personal use. They are not to be distributed or shared without the written permission from the Course Instructor.

ASSESSMENTS OF LEARNING

Your course grade will be determined according to the following components:

Items	Marks	Notes
Class Participation	10%	It includes both attendances to lectures and participation
Assignments	20%	Assignment #1 – 5% Assignment #2 – 10% Assignment #3 – 5%
Mid-term Exam	35%	
Final Exam	35%	

Assignment #1 tests the student ability to complete economic and technical aspects of a first-pass feasibility evaluation of a chemical or biological process. (Module 2)

Assignment #2 tests the student ability to complete aspects of a Techno-economic Assessment, including the use of its results to frame strong research and development programs for novel chemical or biological processes (Module 3)

Assignment #3 tests the student ability to complete aspects of the technical work involved in the scale-up of equipment in chemical and biological processes, including the determination of relevant dimensionless numbers. (Module 4)

The Midterm Exam tests the student comprehension of the material covered between Week 1 and Week 8, more specifically how to complete and properly use the results of feasibility studies and Techno-Economic Assessments of novel chemical and biological processes. (Module 1 to 3)

The Final Exam tests the student comprehension of the material covered between Week 9 and Week 13, more specifically how to use dimensional analysis and pilot plant tests in the scale-up of equipment, how to use engineering drawings to translate development work results into engineering designs, and how patents can constraint or affect or frame the development work around a novel chemical or biological process. (Module 4 to 6)

RECORDING OF SYNCHRONOUS VIDEO LECTURES

Recording of the lectures will not be offered.

RESPECTFUL ENVIRONMENT

The following provides a set of expectation for appropriate conduct in this course.

- *UBC Respectful Environment Statement*

  The University of British Columbia envisions a climate in which students, faculty and staff are provided with the best possible conditions for learning, researching and working, including an environment that is dedicated to excellence, equity and mutual respect. The University of British Columbia strives to realize this vision by establishing employment and educational practices that respect the dignity of individuals and make it possible for everyone to live, work, and study in a positive and supportive environment, free from harmful behaviours such as bullying and harassment.

- *For synchronous meetings in online courses*

  ARRIVE EARLY Join the session a few minutes before the start time to ensure that your Internet connection, webcam, and microphone are functioning properly.

MUTE YOUR MIC If you are not speaking, please mute your microphone as it may pick up on background noises which can distract other participants.

USE THE "RAISE HAND" FEATURE If you would like to speak or ask a question, you can make your intentions known to the moderator without having to unmute your mic by using the raise hand feature. Remember to "lower hand" once you have spoken.

- *For Zoom sessions enabled during in-person classes*

MUTE YOUR MIC Please mute your microphone as it may pick up on background noises which will be distracting during the lecture.

BE AWARE that while your instructor may be making a Zoom session available, they may not be able to monitor the Zoom Chat or Raise Hand feature. Live-streaming is being provided to aid students in staying up to date with course material if they cannot attend class, but it is not the primary mode of instruction.

- *For discussion boards*

NO PROFANITY or DEROGATORY TERMS Everyone in the class as well as your instructional team can see course discussion boards. Please be polite and professional in your messaging

RESPECTFUL ENVIRONMENT in Digital Forums As per the UBC statement on Respectful Environment, disrespectful behaviour will not be tolerated. Do your part to ensure that everyone feels comfortable using the discussion board as a resource.

- *When contacting instructors or teaching assistants*

Please include the course code in your subject heading, and include your name and student number in all communications. Please refer to this syllabus and updates on Canvas first before asking your question – the information you seek may already be published.

COURSE POLICIES

If you are sick, it is important that you stay home – no matter what you think you may be sick with (e.g., cold, flu, other).

Do not come to class if you have Covid symptoms, have recently tested positive for Covid, or are required to quarantine. You can check this website to find out if you should self-isolate or self-monitor: http://www.bccdc.ca/health-info/diseases-conditions/covid-19/self-isolation#Who.

Your precautions will help reduce risk and keep everyone safer. In this class, remote class access is provided and intended to provide flexibility so that you can prioritize your health and still be able to succeed. But you must attend in-person classes if you are not sick and in region.

If you are sick on a final exam day, do not attend the exam. You must apply for deferred standing (an academic concession) through Engineering Academic Services no later than 48 hours after the missed final exam/assignment. Students who are granted deferred standing write the final exam/assignment at a later date.

For additional information about academic concessions, see the UBC policy here: http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,329,0,0

UNIVERSITY POLICIES

UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access. UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions.

Details of the policies and how to access support are available on **the UBC Senate website.**

The University is commited to support students in their academic pursuits through the application of academic concessions in the event that students experience unanticipated events or circumstances that interfere with their ability to accomplish academic work. Academic concession policy is available on https://vancouver.calendar.ubc.ca/campus-wide-policies-and-regulations/academic-concession. Any request for in-term concession should be done through the following site, https://academicservices.engineering.ubc.ca/exams-grades/academic-concession/, and follow up with the course instructor.

Keep in mind that some UBC courses might cover topics that are censored or considered illegal by non-Canadian governments. This may include, but is not limited to, human rights, representative government, defamation, obscenity, gender or sexuality, and historical or current geopolitical controversies. If you are a student living abroad, you will be subject to the laws of your local jurisdiction, and your local authorities might limit your access to course material or take punitive action against you. UBC is strongly committed to academic freedom, but has no control over foreign authorities (please visit http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,33,86,0 for an articulation of the values of the University conveyed in the Senate Statement on Academic Freedom). Thus, we recognize that students will have legitimate reason to exercise caution in studying certain subjects. If you have concerns regarding your personal situation, consider postponing taking a course with manifest risks, until you are back on campus or reach out to your academic advisor to find substitute courses. For further information and support, please visit: http://academic.ubc.ca/support-resources/freedom-expression

OTHER COURSE POLICIES

- Accessibility: UBC is committed to accommodating students with special needs in its instructional programs. If you have special needs, please meet with a the UBC Centre for Accessibility advisor to determine for what accommodations/services you are eligible. If you require special assistance or accommodations for this course, please contact me as soon as possible with your information from the UBC Centre for Accessibility (https://students.ubc.ca/about-student services/centre-foraccessibility).
- Religious observance: You will not be penalized because of observances of your religious beliefs. Whenever possible, you will be given reasonable time to reschedule any academic assignment that is missed due to participation in a religious observance. You are responsible for informing me of any intended absences for religious observances in advance.
- Academic integrity: You must follow UBC's policy on plagiarism and other forms of academic misconduct and are responsible for familiarizing yourself with UBC's campus-wide policy on "Academic Misconduct" (http://www.calendar.ubc.ca/vancouver/?tree=3,54,111,959). For further information, see https://learningcommons.ubc.ca/academic-integrity/.

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Classes may not be recorded without prior permission from the instructor.