Teaching Dossier

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Initials:

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1. Introduction

This teaching dossier summarizes my contributions to creating an exceptional learning environment at the University of British Columbia (UBC) and beyond. My focus since being hired at UBC has been teaching and learning excellence in my own classroom, collaborating with and training other educators for impact beyond my own classroom and contributing to the department, faculty, university and beyond through service to advance teaching and learning.

2. Teaching Excellence

I have facilitated learning in a variety of contexts since starting my position at UBC. I am part of the teaching team for the first-year introduction to engineering courses, Applied Science (APSC) 100/101. These courses are taken by all first-year engineers, around 1000 students. Teaching in this context requires working with faculty from a variety of other departments and ensuring students get a holistic view of the engineering profession.

I have taught a variety of courses within my department, including large lecture courses, such as CHBE 241: Material and Energy Balances, which has a class size of roughly 190 students. This course has students majoring in CHBE as well as integrated engineering, and I have to ensure the course speaks to both these audiences. I also deliver hands-on laboratory courses notably CHBE 362: Process and Environmental Laboratory. I am also part of the teaching team for our departmental capstone design course (CHBE 453/454), and I will be leading this team in the 2019-2020 academic year.

The experience I have gained in these diverse teaching contexts have given me insight into student progression and development throughout their undergraduate degree. I have used this to help improve my teaching by striving to get students to see the larger picture between these courses. My teaching experiences have also informed my educational leadership work, especially around curriculum enhancement, which is described in section 3 of this document.

In this section I include a summary of courses I have taught and teaching evaluations as well as curricular contributions I have made to select courses. I do not describe all my teaching activities, but rather focus on a key selection to give a sense of areas where I have had particular impact.

2.1 Teaching Philosophy

My actions in the classroom are driven by providing a space where students can learn, experiment, ask questions, and ultimately master engineering professional practice. In order for students to be able to be successful at these tasks, I focus on building trust with students as well as creating significant learning experiences and I will further describe what I mean by these terms and how I enact them in my courses.

In Ken Bains' book, "What the Best College Teachers do", one chapter describes the importance of trust between instructor and student and how this is an essential part of good educational practice [1]. Through openness to dialogue and feedback, I show my students that I have their best interests at heart and that I want to see them learn and succeed. I encourage students in my courses to give me feedback and offer a variety of ways to do this including through face to face conversations, midterm course surveys, online discussion boards, and anonymous surveys accessible anytime during the course. I am open to their thoughts and suggestions and will acknowledge and respond to each of them, although the response may be that I will not act on a suggestion for a certain reason. I also communicate trust in my students by encouraging them to work together on assignments and giving them materials to help with their independent study. While doing this, I encourage them to ensure they truly understand the material as they will need to demonstrate it later on in the course they are in, as well as other courses, or in their professional practice. I believe this relationship of trust engages both students and myself in thinking about how we can further improve.

Dee Fink argues that in order to create significant learning experiences, teachers must challenge students, use active forms of learning, care about students, interact well and have good systems for feedback assessment and grading [2]. There are some linkages between this and Ken Bains' observations on the importance of trust, notably in instructors showing their care for students, as well as interaction and feedback. In the courses I teach, I attempt to ensure students have sufficient practice with material and that they get feedback in a timely manner. Some of this is done in the class, through active learning techniques that I have incorporated such as with the use of worksheets and design examples. With practice outside of class, I have worked to develop more rapid and effective feedback tools through the development of online homework questions and use of instructional rubrics. These tools I have developed help to actively challenge students, and give them relevant and timely feedback to improve their learning.

By creating a strong relationship built on trust between students and myself, as well as combining elements that create significant learning experiences, I believe I am driving student learning forward and creating spaces where students can explore and ultimately be successful.

2.2 Courses Taught and Teaching Evaluations Summary

2.2.1 Courses Taught

A summary of the courses I have taught, organized by term is included in Table 1. This is provided for reference and is the same table as in the UBC CV.

Table 1: Summary of courses taught and scheduled to be taught in reverse chronological order by ascending course number

Session	Course Number	Total Scheduled Hours	Class Size	Total Hours Taught per Course			
				Lectures	Tutorials	Labs	Other
2019W2	APSC 101 – 202	25 Lecture 24 Studio	199	7	0	0	0
2019W2	APSC 101 - 204	25 Lecture 24 Studio	189	7	0	0	0
2019W2	APSC 366	39 Lecture	60	9	0	0	0
2019W2	CHBE 376	39 Lecture 12 Tutorial	119	39	12	0	0
2019W1 &W2	CHBE 453-454	26 Lecture 104 Advising	123	2	0	0	104
2019W1	APSC 100 - 102	25 Lecture 24 Studio	198	5	0	0	0
2019W1	CHBE 220	39 Lecture 24 Tutorial	115	39	24	0	0
2018W2	APSC 101 – 202	25 Lecture 24 Studio	149	7	0	0	0
2018W2	APSC 101 - 204	25 Lecture 24 Studio	182	7	0	0	0
2018W2	APSC 366	39 Lecture	48	9	0	0	0
2018W2	CHBE 376	39 Lecture 12 Tutorial	129	39	12	0	0
2018W1 &W2	CHBE 453-454	26 Lecture 104 Advising	106	0	0	0	104*
2018W1	APSC 100 - 102	25 Lecture 24 Studio	202	4	0	0	0
2018W1	APSC 100 - 103	25 Lecture 24 Studio	180	4	0	0	0
2018W1	CHBE 241	39 Lecture 12 Tutorial	178	39	12	0	0
2018W1	CHBE 243	13 Lecture 12 Tutorial	117	13	12	0	0

2018W1	CHBE 362 - 101	2 Lecture 10 Dry Lab 18 Wet Lab	69	2	10	18	0
2018W1	CHBE 362 - 102	2 Lecture 10 Dry Lab 18 Wet Lab	67	2	10	18	0
2017W2	APSC 366	39 Lecture	49	9	0	0	0
2017W2	CHBE 376	39 Lecture 12 Tutorial	128	39	12	0	0
2017W1	CHBE 241	39 Lecture 12 Tutorial	190	39	12	0	0
2017W1	CHBE 362 - 101	2 Lecture 10 Dry Lab 18 Wet Lab	64	2	10	18	0
2017W1	CHBE 362 - 102	2 Lecture 10 Dry Lab 18 Wet Lab	48	2	10	18	0
2016W1	CHBE 241	39 Lecture 12 Tutorial	193	39	12	0	0

*For CHBE 453/454 – this 104 hours is used for meeting with design groups twice per week.

2.2.2 Student Evaluations of Teaching

A summary of student evaluations of teaching, organized by course number with CHBE courses listed first, is included in Table 2. These show strong evaluation results in many courses I have taught. Full evaluation data, including student comments from these student evaluations can be found in Appendix A.1. I will draw from these evaluations in describing the impact of changes I have made to courses.

Table 2: Summary of Student Evaluations of Teaching

The table shows mean student evaluation scores on a 5 point scale*. Note that in 2018W1 UBC moved to using interpolated means rather than means for scoring. Numbers from 2018W1 onwards contain this interpolated mean and an extra decimal place is also indicated with this new system.

Course	***Year***	***Response Rate***	*The instructor made it clear what students were expected to learn*	*The instructor communicated the subject matter effectively.*	*The instructor helped inspire interest in learning the subject matter*	*Overall, evaluation of student learning (through exams, essays, presentations, etc.) was fair.*	*The instructor showed concern for student learning.*	*Overall, the instructor was an effective teacher.*
CHBE 241	*2018 W1*	*154/179 (86%)*	*4.42*	*4.20*	*3.86*	*4.35*	*4.44*	*4.29*

CHBE 241	*2017 W1*	*120/190 (63%)*	*4.2*	*3.8*	*3.6*	*3.8*	*4.6*	*4.1*
CHBE 241	*2016 W1*	*120/193 (62%)*	*4.2*	*3.8*	*3.7*	*3.7*	*4.6*	*4.0*
CHBE 243	*2018 W1*	*65/117 (56%)*	*3.74*	*3.85*	*4.05*	*3.76*	*4.06*	*4.11*
CHBE 362 – 101	*2018 W1*	*26/69 (38%)*	*4.29*	*4.17*	*4.27*	*4.06*	*4.50*	*4.50*
CHBE 362 – 102	*2018 W1*	*24/67 (36%)*	*4.14*	*4.14*	*4.14*	*4.59*	*4.50*	*4.30*
CHBE 362 – 101	*2017 W1*	*24/64 (38%)*	*4.0*	*4.1*	*3.9*	*3.8*	*4.3*	*4.2*
CHBE 362 – 102	*2017 W1*	*18/48 (38%)*	*4.2*	*4.4*	*4.1*	*4.1*	*4.7*	*4.6*
CHBE 376	*2018 W2*	*70/129 (54%)*	*4.94*	*4.93*	*4.81*	*4.82*	*4.89*	*4.94*
CHBE 376	*2017 W2*	*65/128 (51%)*	*4.6*	*4.6*	*4.4*	*4.4*	*4.7*	*4.7*
CHBE 453/454	*2018 W2*	*28/106 (26%)*	*3.73*	*3.75*	*3.83*	*4.09*	*3.91*	*3.85*
APSC 101 – 202	*2018 W2*	*43/149 (29%)*	*3.95*	*4.04*	*3.61*	*4.04*	*3.94*	*3.93*
APSC 101 - 204	*2018 W2*	*46/183 (25%)*	*4.00*	*4.07*	*3.68*	*3.89*	*3.82*	*3.88*
APSC 100 - 102	*2018 W1*	*116/202 (57%)*	*3.99*	*3.93*	*3.54*	*3.95*	*3.59*	*3.76*
APSC 100 - 103	*2018 W1*	*75/180 (42%)*	*4.05*	*3.99*	*3.54*	*3.83*	*3.68*	*3.91*
APSC 366	*2018 W2*	*15/48 (31%)*	*4.31*	*4.56*	*4.56*	*4.56*	*4.22*	*4.44*
APSC 366	*2017 W2*	*13/49 (26%)*	*4.1*	*4.2*	*4.0*	*3.8*	*4.3*	*4.3*

*1 – Strongly Disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, 5 – Strongly Agree

2.2.3 Peer Evaluations of Teaching

Peer evaluations of teaching can be found in Appendix A.2. I will draw from these evaluations in describing the impact of changes I have made to courses.

2.3 Classroom Instruction

2.3.1 CHBE 241: Material and Energy Balances

Description

This course is taken as a core course by students in Chemical and Biological Engineering and Integrated Engineering. I taught the course in the 2016W1, 2017W1 and 2018W1 terms with roughly 190 students enrolled in each iteration. This course covers the fundamentals of analyzing chemical and biological process systems in terms of material and energy flows. Non-reactive and reactive processes are analyzed. Separation units are evaluated using thermodynamic principles for multiphase systems. The laws of thermodynamics are introduced and applied to characterize reactive and non-reactive systems. Students are introduced to block and process flow diagrams.

Structure and organization

The course consists of two weekly 90-minute lectures supplemented by a weekly one-hour tutorial sessions. Course lecture time is mainly used to deliver theoretical content with breaks for practicing examples in small groups. I try to use some of the small group exercises informed by literature such as the article outlining “teaching methods that work” by Felder, Woods, Stice and Rugarcia [3]. More in-depth examples are explored in the tutorials which are organized and led by myself. In the 2016W iteration tutorials were scheduled as six two-hour tutorial sessions taking place on alternating weeks throughout the semester, however I requested to change this based on student feedback that they wanted more regular contact for practice sessions. The schedule was switched to one-hour weekly tutorials in 2017W and onwards and I have found these weekly sessions to be more effective for students. When starting to teach the course in 2016W, the previous instructor provided the presentation notes but I did not have permission to use editable PowerPoint files and as a result built new lecture slides from scratch in order to be able to customize them. I also chose to update to a newer textbook at the same time.

Reflection on student evaluations

Students appear to appreciate the efforts I have put into the course as demonstrated by the consistent high rating (~4.5/5) for instructor concern for learning. I also received the departmental Teaching Award from the CHBE Undergraduate Club for excellence in 2nd year teaching in 2016W. As shown by student comments in 2016W, the course covers a wide range of material and it can be difficult to practice this material, as well as see how the various topics are related. Over course iterations, I have worked to more clearly communicate the subject matter by organizing a variety of learning aids to scaffold student learning outside of the classroom. Evidence for this can be seen in the progression of student comments from year to year. I further describe these learning aids in the section that follows this one. One item that I still struggle with is engaging the Integrated Engineering students who may not see the relevance of this course to their future studies focusing on civil, computer, electrical or mechanical engineering. My goal in future years is to try to engage more of these students by providing examples relevant to these disciplines.

Reflection on peer evaluations

In a peer evaluation from 2016W1 it was noted that though the class content was logically structured, it could have been better paced when dealing with complex problems and the use of excel to solve these problems. I have worked to improve in these areas by more clearly linking course content to engineering application. I have done this by incorporating more examples from various industries into the classroom to allow students to see the relevance of the course material as well as motivate students to engage more deeply with the material. Another evaluation was conducted in 2017W and again it was recognized that the class was well organized and students were engaged. One critique from the review was that the writing on a tablet slowed the pace of the class. As a result of the suggestion, I tried using a doc cam and felt pen and this sped up the pace of writing to an adequate level, and also allowed more flexibility in terms of bringing back previous pages of notes to answer student questions. As a result, I now regularly use this method and scan the notes I have made after class so students have access to a copy of these notes.

Scaffolding student learning

In 2017W, I was awarded a TLEF to scaffold student learning through the curation, development, and provisioning of openly available multi-media resources for CHBE 241. This project was shaped by student feedback from the first course iteration. I led a team of graduate and undergraduate students, with a focus on developing four resources: supplemental course notes, WeBWorK online homework with instant feedback, supplementary study guides and a long-answer problem bank. The course syllabus and samples of some of these resources can be found in Appendix A.3 as well as online where noted. More details on each of these resources are provided below:

A. **Supplemental course notes**
   Supplemental course notes were developed to explain key course concepts and provide sample problems and solutions. These notes are openly available on the UBC Wiki at http://wiki.ubc.ca/Documentation:CHBE_Exam_Wiki . These have currently been viewed over 3,800 times.

B. **WeBWorK online homework**
   Regular practice and feedback can greatly enhance the learning process. In the 2016W course iteration, I introduced weekly online homework, rather than homework every two weeks, to give students more regular practice and feedback. The homework was manually graded taking roughly one week to grade and return, which turned out to be a significant delay in the context of this course. In order to offer students more rapid feedback on their learning, I have developed 50 problems spread across ten weekly problem sets on the WeBWorK online homework platform. These problems provide students with unique problem variables and solutions as well as instant feedback. Having been tested, the problem sets are now also shared through

UBC's folder on the WeBWorK Open Problem Library (OPL), which can be accessed online at the following address: https://github.com/openwebwork/webwork-open-problem-library/tree/master/Contrib/UBC . These exercises provide good practice for students, but it is also important to prepare them to analyze open-ended problems and explain their solutions. As such, I have combined these WeBWorK problems with longer form written problems to ensure students are prepared to analyze and explain concepts.

C. Supplementary study guides

Students in CHBE 241 commented that they access a variety of video materials produced outside of UBC to supplement their learning. In order to support students wishing to access screencasts I have organized a repository of relevant online videos and listed these by course learning objective. In these guides I also include links to the online course notes and relevant textbook chapters. A sample guide is included in Appendix A.3.

D. Long-answer problems

The Math Exam Wiki at UBC collects previous exams and solutions and provides these to students in an easy to access format. I sought to replicate this approach in CHBE 241 and made available previous exams and problem sets along with sample solutions which students can use for practice. This long answer problem can be found on the UBC Wiki: http://wiki.ubc.ca/Documentation:CHBE_Exam_Wiki.

2.3.2 CHBE 243: Introduction to Chemical Engineering Process and Technology

Description

The course is taken as a core course by students in Chemical and Biological Engineering. I taught the course for its last iteration in 2018W1 with 117 students enrolled. This course introduces students to the discipline of chemical and biological engineering through case studies in a variety of industries.

Structure and organization

The one-credit course consists of one weekly 50-minute lecture and one weekly 50-minute tutorial. Lectures are delivered by myself as well as a variety of guest speakers from industry and academia. Previously iterations of the course used tutorial for two tests meaning many tutorial slots were not used. In order to introduce students to chemical and biological engineering design, I developed a variety of team-based design exercises to be run in five tutorials during the course. I also used two tutorials before and after the design exercises to measure student design knowledge using a general design assessment tool developed at Queen's University [4]. The results from this showed no significant change in student design methodology. We suspect the tool may be too general and have adapted a different tool for future measurements based on concept mapping to see if the effects are the same.

Team design exercises

A sample of one of the five design exercises developed can be found in Appendix A.4. Each team design exercise involved a pre-reading assignment consisting of 2 to 3 pages introducing a chemical and/or biological engineering design concept. This was followed by students completing a five-question multiple choice test on the course learning management system (LMS). In class students were given a brief (5-10 minute) introduction to the exercise. They then worked in groups on these exercises to be completed by the end of the class session with the teaching assistant (TA) and myself circulating to answer questions.

Reflections on student evaluations

Reading over student comments on the course, they appear to focus on two elements. The first is that it can be difficult to relate the material from guest lectures to their course of study. I believe this could be improved by having more framing around the context of why we have invited different guests into the class. Many students have also commented on the design exercises, both positively and negatively. I believe situating these design exercises in the context of a larger course may help students in seeing the relevance of these design steps and also the need to apply the natural and engineering science they are learning. As a department we have decided to revamp our second-year curriculum and have integrate material from this course into a new course, CHBE 220: Founding Principles in Chemical and Biological Engineering I. I believe this will help address these student comments and give students a better idea of how the fundamental concepts they are learning are applied.

2.3.3 CHBE 376: Computer Flowsheeting

Description

The course is taken as a core course by students in Chemical and Biological Engineering. I audited this course in 2016W2 and taught the course in 2017W1 and 2018W1 with roughly 130 students enrolled. This course introduces students to computer flowsheeting and how this is used in the chemical plant design.

Structure and organization

The three-credit course consists of two weekly 80-minute lectures and one 110-minute tutorial every two weeks. Lectures consist of some theoretical background on a given topic, followed by a guided example where students are encouraged to work along in real time on their own laptops. This is then followed by students working through a worksheet example on their own or in small teams while I circulate to answer questions. Tutorials are problem-based with students working on a problem set due at the end of the tutorial period. Myself and the TAs circulate and answer questions during the tutorials.

Expansion of worksheets approach

Previous course iteration used worksheets in roughly half of the classes. With these worksheets, students would work independently on a problem to further their learning. Since beginning to teach the course in 2017W I have expanded this approach to be used in each class. Students are asked to submit the completed worksheet before the next class. This is then given a mark out of 1, mainly based on completion rather than for being entirely correct. Solution summaries for worksheets are made available following the submission deadline. A sample of a worksheet and solution can be found in Appendix A.5. The goal with this approach is to have students work independently on problems with accountability for completion without requiring the time for full grading and feedback. I encourage students to self-evaluate and come to see me if they have questions and I believe it is important to build these self-evaluation skills in students.

Reflections on student and peer evaluations

Student comments mention that they see the applicability of the course, which I believe is critical for student engagement. From the comments, I believe the applied nature of the course and integrated student practice in class sessions aid students in understanding course content. Students in 2017W commented that the feedback could be clearer for assignments. In order to improve this, the assignment marking was all done in canvas in 2018W, using rubrics that students could see following grading. I believe this helped in communicating feedback to students in 2018W as I did not receive many comments on assignment marking. In 2018W I received a peer review in this course that was very favourable in terms of my organization, enthusiasm and engagement of students through in-class exercises. During these exercises I would circulate to help students with any problems they had with their simulations. One critique is that for 120 students, it can be a challenge to get to each of them. I have them working in groups so that they can turn to their peers for help if I am not available initially, but nevertheless, perhaps having a teaching assistant in the class to help answer questions as well may be helpful.

3. Educational Leadership

In this section I discuss my educational leadership philosophy and highlights of my educational leadership contributions. For a complete list of contributions please refer to section 9 of my CV. Educational leadership contributions are ones where the impact is beyond my own classroom. I have organized the contributions I discuss in this document into three categories:

1. Curriculum renewal, development and assessment within the CHBE department.
2. Partnerships with other faculty to develop and deploy impactful pedagogical innovations.
3. Developing educational capacity in the department, university and beyond through creating and facilitating a number of training opportunities.

3.1 Education Leadership Philosophy

Reflecting on my experiences around educational leadership, I believe the role of education leaders is to ensure programs deliver effective learning experiences to students. Students should be engaged in these programs, and graduate having developed and enhanced their knowledge base, critical thinking, communication and teamwork skills [5]. This should also include the capacity for continued learning and skill development such that students can identify their educational needs and continue to grow these important skills.

Programs can move towards successfully incorporate these elements by promoting a faculty culture of evidence-based programs and course design [6]. Faculty must ensure they are using up to date research to inform strategic methods of teaching and program design in order to have continued success in delivering academic programs of a high quality. Support for this must be aligned at the department, faculty and institutional level. Examples of this might include support for the development of expertise in teaching and learning, awards and recognition for significant contributions in these areas, and aligned promotion and tenure policies [7].

In order to be effective, educational leaders must seek out the views of a variety of stakeholders and continually critically engage with them to ensure program quality enhancement [8]. Notable stakeholders include students first and foremost, as well as faculty, alumni and in the case of engineering industry and co-operative learning employers. Students must feel that they are partners in both the learning process within the classroom and more broadly in program improvement. This requires space and time for students and faculty to interact and exchange ideas in a respectful and constructive manner.

The principles that I have described above in terms of quality educational leaders are also reflected in a number of sources that highlight principles of good practice in this domain. This includes Felton's "Principles of Good Practice in SoTL" whose five principles of good practice focus on inquiry into student learning, being grounded in context, engaging students as partners, being methodologically sound and appropriately public [9].

Globalization is putting increased pressure on educational institutions to continually improve programs. Governments, stakeholders and funding agencies are increasingly demanding institutions demonstrate their effectiveness in a number of ways, many times favouring metrics over a judgement-based approach [10]. This may force institutions to focus on measurable outputs, however this may not capture all quality enhancement activities. Educational leaders must ensure their programs are not simply meeting quality assurance standards, but exceeding these in order to be successful in this highly competitive environment [11].

My role as an educational leader is to ensure I am engaging department stakeholders to bring the best to the programs we offer at all educational levels.

3.2 Curriculum Renewal and Development

Part of my mandate when I was hired was the further integration of design education into the curriculum of the CHBE Department’s two programs with these being Chemical Engineering (CHML) and Chemical and Biological Engineering (CHBE). Accomplishing this has required engaging other faculty to discuss and support design integration into their courses. Since my initial appointment I have also begun to take on greater educational leadership in overall curriculum development for the department’s two programs. This notably includes improving our program outcome assessment and continual improvement process.

3.2.1 Design integration (Faculty Associates)

I was selected to be part of the Faculty Associates Program run by the Centre for Teaching, Learning and Technology (CTLT) at UBC. This program appoints faculty for two years and provides funding of $10,000 annually to work on a project of importance to the faculty member and their department or faculty. The focus of my project was on design education in the 2nd and 3rd year of CHBE departmental programs.

The project focused on first identifying best practices in integrating design into the CHBE curriculum. This was done by reviewing practices in other departments at UBC, at other institutions as well as in industry. This process also involved reviewing the current CHBE curriculum. During the time of the project the department was also reviewing and changing the curriculum of its two programs and the project was complementary to this. Methods of measuring the effect of these design experiences on student learning was tested in the second year of the project in CHBE 243. My involvement in the program ended in summer 2019, but work to improve the undergraduate curriculum by integrating design continues. Notably there is a new second-year course (CHBE 220) focusing on design, and I am testing out a new tool to measure design learning through concept mapping. I expect to publish results from this study in the summer of 2020.

3.2.2 Undergraduate Program Evaluation and Renewal TLEF

Working with Dr. Louise Creagh, I co-developed a successful application for the Provost's recent call for Undergraduate Program Evaluation and Renewal TLEF projects. Members of the curriculum and accreditation committee also gave input for the application including Dr. Peter Englezos (dept. head at the time of application), Dr. Charles Haynes (current dept. head), Dr. Dusko Posarac, Dr. Gabriel Potvin and Dr. Bhushan Gopaluni. We have also partnered with Mr. Jim Sibley and the Applied Science Centre for Instructional Support to support the project. The project received funding of roughly $200,000 over 3 years to re-evaluate our continuous improvement process and develop procedures that can be scaled to other units in order to improve academic programs.

Dr. Creagh and I are responsible for the implementation of this project, which started in April 2019. We are working with department staff and a summer co-op student in summer 2019 to implement the initial stages of our plan. This included individually consulting each faculty member on undergraduate program outcomes (known as Graduate Attributes (GAs)) that they report on. These GAs are used in addition to quantitative and qualitative data from students, faculty, co-op employers, and industry as part of our department's continuous improvement process. In the fall, we followed up on these interviews by organizing a faculty retreat. The retreat was well attended with 26 out of 33 faculty in attendance, and all faculty were engaged before the retreat in order to contribute to agenda items. We discussed curriculum renewal for each year level of our undergraduate programs. We also revised our graduate attribute indicators to ensure these were targeted and more effective moving from 60 indicators to 40. Over the summer we also developed surveys to collect self-assessment data from alumni and students and these surveys will be deployed in the 2019W academic year. We are also investigating the development of an annual ungraded assessment, taken by students in each year of the program, to assist in evaluating the learning of key program concepts. Furthermore, in order to better engage students in the curriculum process we have created an interactive curriculum map. A static version of the curriculum map developed from this project can be seen in appendix A.1. We are continuing to move forward on our work on this project over the next two years.

3.3 Pedagogical Innovation

3.3.1. WeBWorK Development

Collaborating with Dr. Agnes d'Entremont from Mechanical Engineering (MECH) and Dr. Negar Harandi from Electrical and Computer Engineering (ECE) I have co-led the expansion of the WeBWorK open-source online homework system to many second-year engineering topics. This system is commonly used in many math department (including the one at UBC) for delivering practice problems with unique values to each student. This allows students to get instant feedback collaborate on solving problems and focus on understanding key course concepts through practice. Previously this software was being used in isolated courses in CHBE, MECH and ECE. We came together to expand the use of this tool across many second-year engineering courses as there is overlapping topics in second-year engineering taught by different disciplines. One example of such a topic is fluid mechanics, taught by CHBE, MECH and Civil Engineering (CIVL), where many concepts, and corresponding practice problems, overlap. In our first year we have implemented WeBWorK in sixteen second-year courses taught in five departments. Many of these common courses are required in more than one program, as such these changes have impacted roughly 750 students in ten programs including: CHBE, MECH, ELEC, CIVL, Engineering Physics, Mining Engineering, Materials Engineering, Integrated Engineering and Geological Engineering.

Our goal was to create WeBWorK problems and then share them to the Open Problem Library (OPL), which is an online openly licensed repository for WeBWorK questions. The OPL contains over 35,000 questions, but these are almost entirely in math subjects. When we began our work, there were only about 260 engineering questions on the OPL in three subjects. Since beginning the project we have created or coded over 1600 problems and created taxonomies to organize problems in ten new subject areas in the OPL. Many of the questions created are now available on the OPL through the WeBWorK interface with the source code stored in the OPL GitHub under the UBC folders: https://github.com/openwebwork/webwork-open-problem-library. This work received funding from multiple sources including $50,000 from a TLEF as well as $7,500 from BC Campus.

3.3.2 CHBE 355/CHBE 356 TLEF

Working with Dr. Bhushan Gopaluni, Dr. Vikramaditya Yadav and Dr. Yankai Cao as well as a number of graduate and undergraduate students we were successful in applying for a Teaching and Learning Enhancement Fund (TLEF) grant to begin April 2018. The project has integrated design and investigation exercises into Kinetics and Reactor Design (CHBE 355) and Process Dynamics and Control (CHBE 356). Both these courses are taken by students in their third year second term in both programs offered by the department. My role was organizing group meetings, managing the overall TLEF plan, including hiring and supervision of students working on the project, and providing feedback on the resources developed. Through this grant we were able to develop, deploy and assess a number of innovative educational resources in the grant's first year. These include the development of Jupyter notebooks for introducing the use of python for the analysis of reactor modelling and process control. The resources developed are openly licensed and those developed to date can be found under our GitHub repository at https://github.com/OpenChemE. The TLEF grant has been renewed for a second year for a cumulative total awarded of $46,330 and we are planning to continue to develop these resources. As a result of this and other pedagogical development projects, I was one of 20 young faculty from the United States and Canada invited to present on educational innovation at the 50th Anniversary Computer Aids in Chemical Engineering. As a follow up, I am working on a collaborative paper for Chemical Engineering Education with 3 other faculty members on the use of computational notebooks in the classroom.

3.3.3 Second-Year Undergraduate Lab Development

I collaborated with Dr. Dhanesh Kannangara to redevelop two second-year labs implemented in CHBE 262 in 2017W. These labs focused on fluid mechanics. I was responsible for designing and overseeing the construction of two experimental setups. I also redeveloped lab manuals, student assignments and trained teaching assistants on use of the setups. One setup focused on pump and system curves including analysis of multi-pump arrangements in series and parallel. The second setup focused on valves types and losses associated with these systems. This unit improved on a previous setup by using clear piping and more straightforward pipe paths, allowing students to more easily operate and understand the implications of the setup. It was also designed to be modular on a moveable table such that it can be re-arranged in the lab.

3.4 Impacts in Training other Educators

When I joined UBC in August 2016, I participated in an Instructional Skills Workshop (ISW) that month. I found it a very helpful introduction to teaching at UBC as well as a chance to meet colleagues from across the institution. Based on my experience I wanted to ensure others had a similar opportunity to hone their teaching.

The following summer, the CHBE department was launching our first iteration of our Vancouver Summer Program (VSP) offering. Dr. Gabriel Potvin was leading the development of our VSP package and I was assisting with this preparation. We had heard from a number of graduate students and postdoctoral fellows in the department they wanted to get some teaching experience, but had limited options for doing this during the winter academic terms. In order to address this we developed a program for training graduate students and postdoctoral fellows to teach as part of the VSP program. The students were paid a stipend to teach 3 three-hour classes in the program. We spaced this teaching out such that students were teaching once per week. Either Dr. Potvin or I were in the class when the students were teaching and we would meet with them to give them feedback each week. In order to prepare students for this experience, I offered a four-hour training workshop followed by an optional ISW. Dr. Potvin and I then followed up with students as they prepared lessons plans and materials for the program. The program has been a success and is ongoing. To date, we have had 22 individuals teach in the program. Some of these students have gone on to teach two-week mini-courses for high school students as part of the UBC Future Global Leaders Program, or teach full VSP courses. This program provides a method for students and fellows in our department of gaining teaching experience, which is becoming increasingly important when applying for academic positions.

I have also been active in facilitating training opportunities for faculty members. I have led Faculty ISWs with CTLT for the past 3 summers., training 17 faculty members I have also co-facilitated workshops as part of the CTLT summer and spring institutes. A list of theses workshops can be found in Section 8e of my CV. Since joining UBC I have also been active in leading the Educational Leadership Network, for this first two years as Communications and Membership Coordinator and now as Co-chair with Dr. Silvia

Bartolic. This is a grassroots network of faculty in the educational leadership stream that offers events and workshops in order to bring together faculty to promote and share educational leadership.

One area of educational leadership that I have been particularly engaged in is open education. Open education seeks to make education and associated resources open for use, sharing and editing. As one example, this can facilitate the creation of more effective learning materials that can be adapted to a classroom context. My engagement in this area is shown by the TLEF projects I have been involved in, most of which aim to build upon or produce open resources. I have also sought to engage colleagues in these endeavours, both at UBC and beyond. At UBC I have given a variety of workshops on open education, and a list of these can be found in section 8e of my CV. Within a broader context I am active in a special interest group focusing on open education as part of the Canadian Engineering Education Association (CEEA). With this group of faculty from across the country, I have developed and delivered four workshops to faculty at the CEEA annual conference. Based on my work in this field, I was selected as one of the BC Campus Open Education Advocacy and Research Fellows in 2018. This has allowed me to showcase the initiatives I have helped lead at UBC to a broader audience.

With all these activities I hope to facilitate spaces where faculty from a variety of backgrounds can exchange ideas, learn and collaborate to promote excellence in teaching, learning and educational leadership at UBC.

4. Service Within and Beyond UBC

I have served in a number of roles and in this section, I highlight service of special relevance to teaching and educational leadership. A full list of service contributions is available in my CV.

Service within UBC

Within the CHBE department I am an active member on the curriculum and accreditation committee. This is shown most notably through the $200,000 TLEF grant the department received, which I helped to co-write and now co-lead with Dr. Louise Creagh. I am also active in contributing to curriculum re-design groups, notably shaping our current re-design of the second-year curriculum and planning for third year curriculum changes.

I have supported co-curricular student initiatives that seek to apply engineering knowledge through my role as a Faculty Advisor to various teams. Getting students to apply their knowledge to problems they are passionate about outside of a course context can deepen their learning and give them a greater appreciation of curricular content.

Outside of the department, I have served on the APSC broad-based admissions committee, having read and ranked 270 student applications in the 2016W and 2017W academic years. I have also served on the UBC Premier Wesbrook Scholar's Selection Committee having ranked 100 applicants for the most prestigious scholarships that UBC awards.

Service to the Community

I am actively involved in the American Institute of Chemical Engineering (AIChE). Much of this involvement centres around undergraduate student programs offered by AIChE. I advise the AIChE Chapter at UBC (known as Envision) as well as many of Envision's design teams including ChemEcar and Internet of Brewing. I also actively encourage and facilitate students to attend regional and national AIChE conferences. Each year I nominate students for AIChE awards and two of our students have received awards each year for the past three years that I have been advisor.

I am active in the Canadian Engineering Education Association (CEEA) and most notably served as logistics chair for the CEEA 2018 conference at UBC. This involved organizing conference accommodation, venue and food for the roughly 300 delegates attending the conference.

5. Conclusions

Over the past three years since my initial appointment, I have contributed to UBC through teaching, educational leadership and service. I have sought to capture highlights of this activity in this dossier. This includes demonstrating exceptional teaching and grounding my practices in scholarly literature. I have advanced education beyond my own classroom by thoughtfully engaging in curriculum renewal, developing pedagogical innovations that have been recognized internationally and learning from, as well as training peers. I have also served UBC through activities within and outside of the university.

I look forward to continuing my work bringing the best in teaching and learning to UBC. In order to do this, I will continue to collaborate with students, colleagues, and external partners.

Thank you for your time and consideration.

6. References

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Appendix: Supplementary Materials

A.1. Student Evaluations of Teaching

A full list of my student evaluations of teaching are not included in this document as they number over 100 pages. They can be accessed on a password-protected UBC personal webpage. The password is UBCSEOT (all caps and all one word) and the page address is: https://blogs.ubc.ca/jverrett/seot/

CHBE 376 2018W Review

THE UNIVERSITY OF BRITISH COLUMBIA
FACULTY OF APPLIED SCIENCE

SUMMATIVE REVIEW OF TEACHING (for ARPT PURPOSES)

Instructor: Jonathan Verrett

Course: CHBE 376 (Computer Flowsheeting & Fluid Properties Estimation) - Core

Dates, Duration of Observation: April 2, 2019 : 11am to 12:30 pm

Teaching Format: Lecture – Hennings 200

Reviewer Name(s) (PRINT): David Wilkinson (CHBE)

Reviewer Signature(s):

Indicate whether you have provided the instructor with a copy of this report.

Yes ☐X No☐

All reports for ARPT purposes will be made available to the instructor.

Indicate whether the instructor was informed in advance of the scheduled visit.

Yes ☐X No☐

Indicate whether the instructor was given an opportunity in advance of the observation session to provide background information about the course and the specific class(es) to be visited

Yes ☐ X No☐

Teaching Dossier Assessment

Confirm that you have examined the teaching dossier prior to the in-class visit

Yes ☐X No☐

I have been aware of Dr. Verrett's teaching dossier since the summer of 2016 when he was hired as an Instructor 1 in our Department to enhance design and laboratory experience for the students. Dr. Verret came with a strong teaching background from McGill where he was involved in a number of teaching initiatives during his PhD. He is always looking for ways to improve his approach to instruction and engage students more effectively, particularly in the large class setting. To this end he is actively involved with conferences and workshops on teaching pedagogy to improve and upgrade his teaching effectiveness.

In-Class Observation and Assessment
Strengths:

Dr. Verrett went right into the lecture after a brief introduction. This is a difficult course to teach as there is a lot of material for the time allotted, and the program simulations are demonstrated on the overhead while assistance is given to students who are having trouble carrying out the simulations on their own laptops. Dr. Verrett did an excellent job of keeping the flow of the class going over the 1.5 hours. During the lecture he discussed some bio and batch processing layouts, different reactor types, "Aspen Plus" and "Super Pro" programming, and got the class to switch batch reactor types and run simulations. During the student run simulations Dr. Verret circulated throughout the class to see how everyone was doing. The students sat in groups of about 4 to 6 students and appeared to be fully engaged in the instruction and running their simulations. The course appears to have clear objectives and is organized in a logical and systematic way.

Weaknesses:

I was not able to detect any issues in the course instruction which overall was done very well. However, one issue I noticed with respect to the course is that with a class of about 90 students it is very difficult for one instructor to answer all questions and help all students during class work on simulations.

Overall Assessment:

Dr. Verrett is an excellent instructor. I found no noticeable weaknesses in his teaching of this course. This course is difficult to teach because it involves carrying out simulations during teaching of the class. The quality of his teaching is certainly at the level of a senior instructor. In addition, Dr. Verrett brings a lot of energy and passion to the classroom which is important for engagement in large classes.

THE UNIVERSITY OF BRITISH COLUMBIA
FACULTY OF APPLIED SCIENCE

PEER REVIEW OF TEACHING (for ARPT PURPOSES)

Instructor:	Jonathan Verrett
Course:	CHBE 241 Material and Energy Balances
Dates, Duration of Observation:	September 28, 2017 12:30-2:00 pm (90 minutes)
Teaching Format:	Lecture
Reviewer Name(s) (PRINT):	Dusko Posarac
Reviewer Signature:	Dusko Posarac

Indicate whether you have provided the instructor with a copy of this report.

Yes X No☐

All reports for ARPT purposes will be made available to the instructor.

Indicate whether the instructor was informed in advance of the scheduled visit.

Yes X No☐

Indicate whether the instructor was given an opportunity in advance of the observation session to provide background information about the course and the specific class(es) to be visited

Yes X No☐

Teaching Dossier Assessment

Confirm that you have examined the teaching dossier prior to the in-class visit

Yes X No☐

After examining Dr. Verrett's teaching dossier, it became evident that he has demonstrated excellence in teaching, introduced and continues to introduce valuable innovations in the curriculum, gave great attention to detail and student feedback, and has excellent teaching evaluations. Dr. Verrett is focused on finding opportunities to continue to improve his own teaching practice and this is shown by his success in obtaining a Teaching and Learning Enhancement Fund (TLEF) grant to improve resources for student in CHBE 241. Dr. Verrett has also focused on finding opportunities to improve design education in the departments programs.

He actively supports and advises extra-curricular student design teams, such as Chem-E-Car which have expanded their membership as well as the number of projects they undertake. He has also been active in analyzing and seeking support for improving design experiences in the CHBE curriculum. This is evidenced by his active role in improving second year lab experiences as well as applying for support through the Centre for Teaching, Learning and Technology (CTLT) Faculty Associates Program.

In-Class Observation and Assessment

Strengths:

Dr. Jonathan Verrett was very well prepared for the lecture I have attended. He provide a theory behind reactive material balance and then went step-by-step through two examples to illustrate the concept. The students were encouraged to ask questions and as a result quite a few questions were asked and the overall atmosphere was very positive and relaxed.

Weaknesses:

It is difficult to identify a weakness with such an excellent and knowledgeable instructor as Dr. Verret. It is perhaps worth mentioning that his presentation was at moments a bit slow-paced, due to the medium used—Jonathan was writing the notes on a screen of a "tablet PC" connected to an LCD projector. This process is significantly slower than writing on overhead transparencies or using chalk/blackboard.

Overall Assessment:

This teaching evaluation is for a core course CHBE 241 Material and Energy Balances. The course is lecture-based with tutorials every second week. This course is a core course for CHBE and IGEN students. In addition, a few students from other Applied Science programs (e.g., Mechanical Engineering), take this course as a technical elective. The attendance was around 70% (140-150 out of 200 students). The visit was before the first mid-term exam.

The session objectives were made clear, with the carefully structured session. The session began with a discussion of the theoretical background, followed by two detailed and well-thought-out examples. The session topic (reactive mass-balances) fits the program objectives completely, covering the following graduate attributes:
Knowledge Base through the introduction of theory for solving reactive balances
Problem Analysis through the application of this theory to two relevant examples
Use of Engineering Tools through the presentation of relevant disciplinary diagrams for organizing calculations.

The session was both well planned and organized, with a thorough attention to detail. The reactive mass-balances, an important topic in chemical engineering, are strongly related to the Material and Energy Balances course aims. For the entire length of the session there was a good flow, keeping students engaged. The instructor demonstrated an excellent understanding of the material, and a capability to communicate it clearly to the students.

Jonathan Verrett is strongly committed to teaching, showing great enthusiasm. The students were interested in the materal being taught and active in class asking questions.

As alreadey mentioned, at moments the pace of the presentation was somewhat slower due to use of an electronic pen on a screen of a PC, compared to using a document camera or even a board and chalk. The amount of material was exactly right and nicely illustrated the content.

Dr. Verrett speaks clearly and audibly. Due to the large number of students (~200) and less than ideally-shaped classroom (CHBE 101), the use of microphone is mandatory. He has a good presentation skills and good rapport with the students. Jonathan was respectful and thanks to his attitude created a positive learning environment, responsive to students' questions.

Even without an "official" encouragement, the students were active and without hesitation asked questions. The two examples selected to illustrate the reactive material balances concept were illustrative with enough detail provided. This seemed an effective technique, giving an impressiong that the majority of students grasped the concept. The examples were from real life, easilly connected with a situation that engineers would encounter in their professional practice.

Dr. Jonathan Verrett displayed a thorough knowledge of the subject which he effectively delivered to the students through a well-prepared, thoughtful, and interesting lecture, illustrated with relevant examples. His rapport with students was well developed. I can with confidence recommend Dr. Jonathan Verret be re-appointed to the rank of Instructor I.

THE UNIVERSITY OF BRITISH COLUMBIA
FACULTY OF APPLIED SCIENCE

PEER REVIEW OF TEACHING (for ARPT PURPOSES)

Instructor: Jonathan Verrett

Course: CHBE 241

Dates, Duration of Observation: November 22, 2016

Teaching Format: Lecture Hall (power point and document camera): CHBE 101

Reviewer Name(s) (PRINT): David Wilkinson

Reviewer Signature(s):

Indicate whether you have provided the instructor with a copy of this report.

Yes X☐ No☐

All reports for ARPT purposes will be made available to the instructor.

INSTRUCTIONS**: (For reference only. Please delete instructions highlighted in red font prior to submission)**

This peer review is intended for use for ARPT purposes. It will be used as one of several indicators provided to departmental, faculty and university committees to assess the overall teaching capability of the instructor teaching the course. The reviewer is expected to highlight the strengths and weaknesses of the teaching skills of the candidate and the learning environment he/she creates and to make an overall determination of the extent to which the candidate demonstrates the level of teaching competence or excellence required for each level of review. This review is not intended to be used to provide detailed formative guidance to the instructor being assessed.

Indicate whether the instructor was informed in advance of the scheduled visit.

Yes ☐X No☐

Indicate whether the instructor was given an opportunity in advance of the observation session to provide background information about the course and the specific class(es) to be visited

Yes ☐X No☐

Teaching Dossier Assessment

Confirm that you have examined the teaching dossier prior to the in-class visit

Yes ☐ No☐X

Comment on the teaching dossier provided by the candidate with respect to philosophy and approach to teaching, evidence of teaching innovation and leadership, contributions to curriculum development, course design, planning and implementation, situation within the overall program, appropriateness and clarity of aims, objectives and content.

In-Class Observation and Assessment

Please provide detailed and illustrative commentary on observed teaching effectiveness. The appended guidelines provide suggested areas with which you may structure your narrative comments (as appropriate). Ensure that you substantiate your conclusions on observed strengths and weaknesses with illustrative examples from the teaching session(s).

Jonathan Verrett (Instructor 1) taught CHBE 241 (Material and Energy Balances) in Term 1 of the 2016 / 2017 year. This is a core CHBE course in which an introduction to Chemical and Biological Engineering units, stoichiometry, phase equilibria, material and energy balances is provided. The course is taught in a large teaching classroom (CHBE 101) with two screens and about 200 students.

I was asked to carry out a peer review to provide an opportunity for feedback on Dr. Verrett's teaching, and potential areas for improvement. I met with him after my attendance to discuss the course and my observations.

Strengths:

Dr. Verrett seemed relatively at ease in a large classroom teaching environment. He walks around a lot (even up the aisles) during the lecture which probably helps to make the class more attentive. His use of overheads in parallel with development of formulae and problem solving using the projector was well done and effective. The pace of development of the solutions and lecturing was at a reasonable pace for most of the lecture, allowing the class to follow the material and ask questions.

During the lecture I attended, Dr. Verrett taught the subject area of heats of reaction and formation. He made a very good comparison of the heats of reaction method versus the heat of formation method. This could be a very dry lecture for some students but Dr. Verrett engaged the students through thoughtful questions and real examples, and calculations to do in class.

Weaknesses:

I found no obvious major weaknesses in Dr. Verrett's teaching style or effectiveness. Perhaps, one suggestion for improvement would be not to finish/rush the material too quickly at the end of the lecture. Another suggestion would be to make sure that the students know how to use Excel and Excel Solver to solve problems in the course. It appeared that some students were struggling with the programing aspect of solving the problem(s). Class engagement is a challenge for all of us so it is always worthwhile to look for methods to improve this.

Overall Assessment:

Based on the assessment provided above, please provide an overall opinion as to the instructor's level of overall teaching effectiveness relative to the specific criteria for the rank under consideration. Note the terms underlined in Appendix B below.

My overall assessment of Dr. Verrett is that he is an excellent overall instructor. The nature of the lesson I attended in this core course was detailed and informative. Dr. Verrett set very clear objectives for the course and the lecture, organized the material in a very logical and systematic way, and he communicated the lecture in an effective and engaging way.

A.3. CHBE 241 Sample Resources

Included in the following pages are sample resources from CHBE 241 including a syllabus with course schedule, a WeBWorK screenshot, a sample assignment and a sample of a supplementary study guide.

CHBE 241 Syllabus

University of British Columbia
Department of Chemical and Biological Engineering

CHBE 241: Material and Energy Balances –Winter 2018 Term 1– 3 credits

Instructor: Dr. Jonathan Verrett (Contact me preferably through Piazza, instructions for setup below, or at jonathan.verrett@ubc.ca), CHBE 427, (604)-827-5685 **Office Hours:** Wednesday, 11:00 – 12:00, in CHBE 427

Lectures: Tuesday/Thursday 12:30-13:50 in SWING 221 on Tuesday CHBE 101 on Thursday (starts Sept 6, ends Nov 30)
Tutorial: Wednesdays. 16:00-17:00 in CHBE 101 (starts Sept 5, ends Nov 30)

Teaching Assistants:

Name	E-mail	Office	Duties
Jun Sian Lee	jslee@chbe.ubc.ca	503	Assignment marking (A2, A6, A8), tutorials, answering general content questions, exam marking
Ruben Govindarajan	ruben.govindarajan@ubc.ca	641	Assignment marking (A1, A3, A5), tutorials, answering general content questions, exam marking
Robe Putra	berobe@chbe.ubc.ca	519	Assignment marking (A4, A7, A9), tutorials, exam marking

Online Contact: For **questions on grading**, please send an email to the instructor and include the TA(s) who are responsible for marking (if known). Please include "[CHBE241]" in the subject line so that I can easily know what course your email is about. **Questions on course content** can be posted through the PIAZZA system. You can login to PIAZZA through the link on the sidebar of the CANVAS website. This will create an account on the Piazza system with an anonymized forwarding email from UBC. You can use your actual name, or a pseudonym depending on your privacy preferences. Use of piazza for questions will ensure your questions get answered in a timely manner and allows other students to answer your questions as well as giving you the chance to post anonymously. You can also send private messages only visible to you and the instructor.

Who to Contact. You can consult with the instructor, TAs and fellow classmates, ideally through PIAZZA, regarding questions on the course material or interpreting assignments. Requests to re-grade exams or assignments should be done in writing within 7 days of date the item is graded and returned to the class. These should be given to the instructor. A short argument about why the specific exam or assignment questions should be re-graded must be included.

Course Text: There is no mandatory course text. However there are a variety of resources available to assist students, all structured similarly to follow the course structure, these include:

- R.M Felder, R.W. Rousseau, and L.G. Bullard, *Elementary Principles of Chemical Processes*, 4th Edition (Available in the bookstore or amazon). I find this book quite useful and well structured and have based our course organization off it. The 3rd edition has nearly identical problems and structure and can also be used. Whether you want a binder-ready version or a hard cover is up to you. My notes will follow this textbook and structure closely.

- Online guides and problem sets created by your colleagues, Victor Chiew, Siang Lim, Jamie Ngai To Lo, Said Zaid-Alkailani, and edited by Dr. Jonathan Verrett can be found at the link below, note that this link may be updated throughout the semester: https://wiki.ubc.ca/CHBE241
- LearnChemE.com hosted at UC Boulder has a variety of screencasts from their material and energy balances course, these can be accessed here: http://www.learncheme.com/screencasts/mass-energy-balances
- Previously this course has used Murphy, R. M. ***Introduction to Chemical Processes: Principles, Analysis, Synthesis***, this is also a good text and can provide practice problems, however, I will not be following its structure for content.

Sample questions are available in the online modules as well as on the exam wiki found here: https://wiki.ubc.ca/CHBE241. Extra practice questions can also be found in the **End of Chapter Questions** in the Felder textbook provide a good resource for testing your knowledge with some of the numerical final solutions found at the back of the book. **Test Yourself** questions found in the textbook also provide a good set of questions to test your knowledge with all answers provided in the back of the textbook**.**

Course prerequisites: officially there are no prerequisites, however, you all have successfully completed the first year of an engineering program. This course draws on previous chemistry (CHEM 154), physics (PHYS 157) linear algebra (MATH 152) and calculus (MATH 100/101) courses.

Academic Calendar Entry: Introduction to Chemical and Biological Engineering; units; stoichiometry; phase equilibria; material balances; energy balances. *This course is not eligible for Credit/D/Fail grading.* [3-0-1]

Course Outcomes: By the end of the course, you should be able to **analyze** chemical and biological processes using appropriate material and energy balances to specify process streams. This is supported by the following outcomes:

- Solve stoichiometry and thermodynamics problems using process variables
- Identify known quantities, unknown quantities and assumptions in process engineering
- Retrieve or estimate information from engineering flow sheets and steam tables
- Analyze chemical & biological processes to determine appropriate solution strategies
- Create block flow diagrams (BFDs) and identify components in process flow diagrams (PFDs)

POLICIES AND PROCEDURES

- **Academic integrity.** The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences.

  A more detailed description of academic integrity, including the University's policies and procedures, may be found in the Academic Calendar at - http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,286,0,0
  Guides on avoiding plagiarism can be found at the following link - http://learningcommons.ubc.ca/resource-guides/

  In this course:

  - **You can** work with others when solving assignment questions by sharing solutions strategies, however your solutions must be your own. Make sure you understand the material, copying may get you 100% on the assignment, but will not help when it comes to quizzes and exams, as well as the rest of your studies and your career. Directly copying solutions is considered cheating in this class.

- **You can** discuss a strategy of how to solve a problem with others in the course, you cannot however copy their solutions. The goal of this is to promote learning and cooperation between individuals, if you simply copy an assignment you will learn much less than discussing and understanding a solution method and then attempting to implement it yourself.
- **You cannot** collaborate with anyone during individual assessments such as the individual portions of exams.
- If you have questions on any of these points it is your responsibility to clarify with the instructional team before undertaking any activity (you can ask on PIAZZA). If you think what you are doing may be inappropriate, **please ask** before submitting work**.**

- **WeBWorK.** Will be completed through the online system and can be accessed through a link on Canvas. If you have any technical issues with this system, please contact the instructors through PIAZZA or email Jun Sian Lee (jslee@chbe.ubc.ca) while cc'ing Jonathan Verrett (jonathan.verrett@ubc.ca)

- **WeBWorK Submission Policies** WeBWorK assignments cannot be submitted after the deadline since numerical solutions will be released after the due date. It is your responsibility to find the solution method by discussing with other students, the TAs or instructor.

- **Exams**. There will be two midterm exams held in class during the semester and one comprehensive final exam. *All exams will be closed-book, with a formula sheet provided.* The formula sheet will be provided in advanced and it is recommended you use it to practice solving problems. No electronic devices other than a calculator are allowed during exams (including watches). A cell phone may not be used as a calculator.

- **Missed Exams** If you miss an exam or assignment without either a certified medical excuse or prior instructor approval, you will receive a mark of 0 on that exam. Midterm exams missed with certified medical excuses or prior instructor approval will have half the weight moved to the final exam and the other half moved to the other midterm. Assignments missed will have the weight redistributed to other assignments with an equal weighting.

- **Tutorials**. We will focus on problem solving in the tutorials. Please bring your calculator, equation sheet, class notes, textbook (if any) and paper.

- **Laptop and cell phone use:** Technology can be useful in the classroom, but may also prevent learning by distracting you and others. Please refrain from using technology in the classroom for purposes such as messaging, playing games, social media, texting, etc. Acceptable uses of laptops include taking notes and looking up relevant course information. Please be considerate of your classmates as your laptop or phone may not only be a distraction for you, but also those around you. Please put your cell phone on silent when you are in the classroom.

- **Instructors' commitment**. You can expect me and the TAs to be courteous, punctual, well organized, and prepared for lecture and other class activities; to answer your questions clearly; to be available during office hours or to notify you beforehand if we are unable to keep them; to provide a suitable guest lecturer if I am away; and to grade uniformly and consistently.

- **Consulting with faculty**. I encourage you to discuss any academic or personal question you have by coming to office hours or through PIAZZA. I look forward to getting to know each of you.

- **Access and Diversity**: I hope to make UBC a welcoming and inclusive space for all students. Feel free to ask me questions on any issues and I will do my best to guide you to any resources which might be helpful. You can find a number of university resources at the access and diversity website: http://students.ubc.ca/about/access

- **Course Feedback:** You can give feedback on my teaching and the course at any time by a number of means listed below. If there is a constructive comment that can help improve your learning, please let me know before the end of the course and I will do my best to incorporate your feedback.
    - Face-to-face at office hours or after lectures.
    - As a message through PIAZZA
    - Anonymously, through the feedback link posted on the CANVAS homepage
    - During the middle of the term as an in-class activity
    - At the end of the course through formal course evaluations

Assessment Criteria and Grading

- The course is graded on a percentage basis, based on the standard UBC grading scheme. 50% of greater is required to pass the course. The course is **not graded based on a distribution** as all practicing engineers are expected to have adequate technical knowledge in their fields. Your performance depends only on how you do, not on how everyone else in the class does. It is therefore in your best interests to discuss and help your classmates, as this has been shown in literature to **improve your own learning as well as their learning**.

- Assignments (9 total, highest 8 count) - 10% of final grade - Completed individually – These will focus on practice problems and will be completed on both WeBWorK and on paper. You will also want to practice on your own time. The highest 8 assignment grades will be weighted equally and used to form the 10% of the course grade. The paper portion will be due by 4pm to the assignment dropbox near the CHBE office on the 2nd floor of the CHBE building and the WeBWorK portion will be due at midnight the assigned due date. Late submissions will not be accepted.

- Midterms (20% each) – 40% of final grade- 1.25 hours each- covers all material in the class up to a point that will be specified. These may have some multiple choice component as well as longer answer sections. Closed book with formula sheet provided.

- Final - 50% of final grade - 3 hours - covers all course content. Closed book with formula sheet provided. If you get higher on the final than on the midterms, I will use your final mark in place of any midterms that are lower. I recommend you still try as best you can on the midterms and not rely on the final.

Exam formats, in terms of number of question and type, will be released prior to the exams. Links to previous midterm and final exams will be made available online through Canvas as well as some already being available at the following link: https://wiki.ubc.ca/CHBE241

Draft Class Schedule

DATE	**READ** (Chapters in text)	**SUBJECT**	**DO (due date)**
Week 1 9/3-9/7	Syllabus, Course Policies,	Introduction to the course	Access CANVAS and PIAZZA (link on CANVAS homepage)
Week 2 9/10-9/14	Chapter 2, 3	Introduction to engineering calculations; process data representation and analysis Tutorial 1	
Week 3 9/17-9/21	Chapter 4.1 – 4.4 Add/Drop deadline without a W (Sept 18)	Fundamentals of material balances; Balances on multiple process units; Tutorial 2	Assignment 1 (9/17)
Week 4 9/24-9/28	Chapters 4.5 - 4.6	Recycle and bypass streams; Chemical reaction stoichiometry Tutorial 3	Assignment 2 (9/24)
Week 5 10/1-10/5	Chapter 4.7	Balances on reactive processes; Tutorial 4	Assignment 3 (10/1)
Week 6 10/8-10/12	Chapter 4.7-4.9; Chapter 5-5.2	Balances on reactive processes (cont'd); Combustion reactions; Liquids, solids and ideal gasses Tutorial 5	Assignment 4 (10/9 – changed due to Thanksgiving)
Week 7 10/15-10/19	Chapter 6-6.4	Single component gas-liquid Systems Tutorial 6	Assignment 5 (10/15) **Midterm #1 (10/18) Up to & including CH. 5, In Class**
Week 8 10/22-10/26	Chapter 6.5-6.7; Chapter 7-7.4	Multi-component gas-liquid Systems; solid-liquid, liquid-liquid and gas-solid systems; Introduction to Energy Balances Tutorial 7	
Week 9 10/29-11/2	Chapter 7.5– 7.6; Ch 8-8.2	Thermodynamic tables and applications of energy balances; Energy balance calculations and pressure changes Tutorial 8	Assignment 6 (10/29)
Week 10 11/5-11/9	Ch 8.3	Energy balance calculations and pressure changes Tutorial 9	Assignment 7 (11/5)
Week 11 11/12-11/16	Chapter 8.4 – 8.5	Phase change and heat of mixing Tutorial 10	Assignment 8 (11/13 – changed due to remembrance day) **Midterm #2 (11/15) Up to & including CH. 8.3, In Class**
Week 12 11/19-11/23	Chapter 9 - 9.3	Heats of reaction and formation Tutorial 11	
Week 13 11/26-11/30	Chapter 9.4 – 9.6	Balances on reactive processes and combustion Tutorial 12	Assignment 9 (11/26)
Final Exam Period			**FINAL EXAM (TBD)**

CHBE 241 WeBWorK Screenshot

(6 points) **local/setModule-1-Questions/Mod1_Q2**

The Solvay process is used to produce soda ash (Na_2CO_3), which is used to make glass, paper, soaps, detergents and can be converted to baking soda to make delicious baked goods. The process consumes limestone $(CaCO_3)$ and sodium chloride $(NaCl)$ (known commonly as salt) and also produces calcium chloride $(CaCl_2)$ as a byproduct, Assuming we wish to produce 1450 tonnes of soda ash per day in our plant, what are the required feed rates of limestone and salt, as well as the rate of production of calcium chloride in tonnes/day?

- Limestone feed in tonnes/day...... :* [ ] $tonnes/day$
- Sodium chloride feed in tonnes/day...... :* [ ] $tonnes/day$
- Calcium chloride byproduct in tonnes/day...... :* [ ] $tonnes/day$

If the current prices for bulk quantities of these materials are $95 for sodium chloride $(NaCl)$, $89 for limestone $(CaCO_3)$, $114 for calcium chloride $(CaCl_2)$ and $248 for soda ash (Na_2CO_3) per tonne respectively. What is the gross economic potential in $/yr of this process if the plant operates 330 days per year (it doesn't operate all 365 due to maintenance)? Assuming operating costs are $100 per tonne of soda ash produced and the capital cost of the plant will be $132,000 per tonne of soda ash capacity of the plant ($ cost to build the plant per tonne of soda ash produced per day), what is the net economic potential, and return on investment?

- Gross economic potential (GEP)...... :* [ ] $\$/year$
- Net economic potential (NEP)...... :* [ ] $\$/year$
- Return on Ivestment (ROI)...... :* [ ] $\%/year$ (eg. 50.2% you would enter as 50.2)

Make sure to use the capital "E" for scientific notation.

Jonathan Verrett **Default_term_CHBE241**
Assignment A2 due 09/24/2018 at 11:59pm PDT

1. **(2 points)** `local/setChapter-4-part1-Questions/Chap4part1_Q1.txt`
Process Classification:
Consider this system: As part of the maple syrup production process. A dilute maple sugar solution is heated in an open tank, part of the water evaporates and leaves the system. This then creates a concentrated maple sugar solution (maple syrup) which is removed and the process can then be repeated.

a) Is the process of creating maple syrup from a dilute maple sugar solution a ...

- batch, transient state process
- semibatch, transient state process
- continuous, transient state process
- batch, steady state process
- semibatch, steady state process
- continuous, steady state process

b) Which term(s) in the general balance equation is/are relevant (meaning non-zero) to analyze the mass balance of water in the tank described above throughout one entire cycle of production, meaning the dilute solution entering the tank to maple suryp leaving the tank? Select all terms that are relevant.

- A. input
- B. output
- C. generation
- D. consumption
- E. accumulation

Answer(s) submitted:

-
-

(incorrect)

2. **(2 points)** `local/setModule-1-Questions/Mod1_Qz1-1C.txt`
Process Classification:
A pharmaceutical company uses bacteria to produce a drug for cancer patients. The process for production of the drug is to add bacteria and nutrients into a reactor and seal it. At some point in time later, another amount of nutrients are added to the reactor, with nothing removed, so the bacteria continue producing the drug. Following nutrient addition the reactor is again sealed until it is eventually opened to recover the final product.

a) What process classification best describes this process?

- batch, transient
- semi-batch, transient
- batch, steady-state
- semi-batch, steady-state

b) Considering the point in time where the additional nutrients are added to the reactor, what would be the general balance equation that would have the terms that best apply to account for the mass in the reactor vessel at that point in time? All of the terms in the equation should be non-zero.

- Accumulation = In - Out
- Accumulation = In
- Accumulation = In + Generation - Consumption
- Accumulation = In - Out + Generation - Consumption

Answer(s) submitted:

-
-

(incorrect)

3. **(1 point)** `local/setModule-1-Questions/Mod1_Qz1-1G.txt`
A pharmaceutical company uses bacteria to produce a drug for cancer patients. The process for production of the drug is to add bacteria and nutrients into a reactor and seal it. At some point in time later, another amount of nutrients are added to the reactor, with nothing removed, so the bacteria continue producing the drug. Following nutrient addition the reactor is again sealed until it is eventually opened to recover the final product.

The company wants to assess the economics of scaling up its process. It estimates a new facility could produce 3.1 tonne of the drug per year and the drugs value would be $100 per gram. This would use 470 tonnes of bacteria and 9.95E+04 tonnes of nutrients per year in the production. The bacteria are valued at $100 per kilogram and the nutrients at $1,000 per tonne. The value of other feeds or products in the process are not deemed to be significant. What is the approximate Gross Economic Potential (GEP) in millions of dollars per year?

Relevant Formulas: Gross economic potential (GEP) = value of products - value of feeds

GEP...... :* $ ___ Million/yr

Answer(s) submitted:

-

(incorrect)

4. **(6 points)** `local/setModule-1-Questions/Mod1_Q2`

The Solvay process is used to produce soda ash (Na_2CO_3), which is used to make glass, paper, soaps, detergents and can be converted to baking soda to make delicious baked goods. The process consumes limestone ($CaCO_3$) and sodium chloride ($NaCl$) (known commonly as salt) and also produces calcium chloride ($CaCl_2$) as a byproduct, Assuming we wish to produce 1450 tonnes of soda ash per day in our plant, what are the required feed rates of limestone and salt, as well as the rate of production of calcium chloride in tonnes/day?

- Limestone feed in tonnes/day...... :* ___ $tonnes/day$
- Sodium chloride feed in tonnes/day...... :* ___ $tonnes/day$
- Calcium chloride byproduct in tonnes/day...... :* ___ $tonnes/day$

If the current prices for bulk quantities of these materials are $95 for sodium chloride ($NaCl$), $89 for limestone ($CaCO_3$), $114 for calcium chloride ($CaCl_2$) and $248 for soda ash ($Na_2CO_3$) per tonne respectively. What is the gross economic potential in $/yr of this process if the plant operates 330 days per year (it doesn't operate all 365 due to maintenance)? Assuming operating costs are $100 per tonne of soda ash produced and the capital cost of the plant will be $132,000 per tonne of soda ash capacity of the plant ($ cost to build the plant per tonne of soda ash produced per day), what is the net economic potential, and return on investment?

- Gross economic potential (GEP)...... :* ___ /year Net economic potential (NEP)...... :* ___ /year Return on Ivestment (ROI)...... :* ___ $\%/year$ (eg. 50.2% you would enter as 50.2)

Make sure to use the capital "E" for scientific notation.

Answer(s) submitted:

-
-
-
-
-
-

(incorrect)

5. **(0 points)** `setHW1/paperA2.pg`

This part of assignment 2 is the portion due in paper form. It is due Sept 24, 4pm in the CHBE 241 dropbox on the 2nd floor outside of CHBE 218 (towards elevators and women's washroom). Note the problem here in WeBWorK may say "0" marks as it is not marked by the WeBWorK system. The marks associated with it are noted below.

Acetone is a common solvent that is used in the manufacture of many chemicals. Since it is a volatile organic compound, there are restrictions on the release of acetone vapour into the environment. A manufacturing company has asked your consulting firm to design an acetone recovery process. Your supervisor has asked you to draw a flowchart based off the following specifications provided to her by the manufacturing company. In this case the company may only emit acetone to the atmosphere in a vapour stream at a concentration of 1500 ppm by mole. In order to capture acetone, the waste vapour stream from the plant is contacted with pure liquid water in an absorption column. The plant's waste vapour stream contains Air (with air defined as 79% nitrogen, 21% oxygen, but you can consider air as one substance for simplicity), 3 weight % of acetone, 2 weight % of water and discharges at 1500 kg/h. The adsorber purifies the vapour and reduces its acetone concentration to 2/3 the emission limit to ensure compliance. Due to the contacting, the molar concentration of water in the purified vapour stream doubles from water's initial molar concentration in the plant's waste vapour stream. The purified vapour stream is then released to the atmosphere. The liquid stream is recovered, containing 19 mole percent acetone and the remainder as water and is further purified later in the process

Draw a block diagram (13 marks) for the absorber and **do a degree-of-freedom (DOF) analysis** (6 marks) to show that it can be solved. Indicate which variables from the flowchart are relevant for each of your items in the degree-of-freedom analysis as well as the species you could use for material balances. Note you do not need to solve for any flows to do this.

After you have completed the DOF **write out all the relevant material balances** (4 marks) using notation from your block diagram you could use to solve this problem using a molar basis.

CHBE 241: Material and Energy Balances
Department of Chemical and Biological Engineering
The University of British Columbia

Week 2-3 Guide

Learning Outcomes (LOs) for this module - By the end of this module you should be able to:

1.A **Relate** units of measure from various measurement systems and convert between them
1.B **Choose** appropriate units for variables based on dimensional consistency of equations
1.C **Classify** steady and unsteady state processes and process types
1.D **Apply** Mass, molar and volumetric flows and convert between them
1.E **Apply** the general mass balance equation to characterize systems
1.F **Construct** input-output and block flow diagrams for chemical processes
1.G **Analyze** overall process economics
1.H **Analyze** the degrees of freedom (DOF) of processes to understand whether they are under specified, adequately specified or over specified
1.I **Apply** a general procedure to organize process flow calculations

Timeline and Resources

Online is for the online course modules which can be currently found at: https://chbe241.github.io/

LearnChemE is for the screencasts provided on that site with regards to material and energy balances, they can be found here: http://www.learncheme.com/screencasts/mass-energy-balances

Felder is for the 4th or 3rd edition of the textbook available at the library, bookstore, amazon, etc. The full reference for the 4th edition is: R.M Felder, R.W. Rousseau, and L.G. Bullard, *Elementary Principles of Chemical Processes*, 4th Edition

LO	Lectures	Online	LearnChemE	Felder
A	11 Sept	1.1	Systems of units	2.2, 2.3
B	11 Sept		Dimensional Homogeneity	2.6
C	13 Sept	1.6		4.1
D	13 Sept	1.3	Density, Mass Flow and Volumetric Flow	3.1-3.3
E	13 Sept	1.8	General Balance for Material Balances	4.2
F	18 Sept	1.4	Flowchart Example	4.3a/b
G	18 Sep	1.9		
H	18 Sep	1.5	Introduction to Degrees of Freedom	4.3d
I	20 Sept	1.8	Material Balance Problem Approach	4.3e

A.4. CHBE 243 Sample Resources

Below is a sample of one of the five design exercises I created for the course to introduce students to chemical and biological engineering design.

CHBE 243 Pre-class Reading and Preparedness Quiz Instructions

Please read pages 20 & 24 from Product and Process Design Principles: Synthesis, Analysis and Evaluation (4th ed.) by W. D. Seider, D. R. Lewin, J.D. Seader, S. Widagdo, R. Gani and K. M. Ng.This section introduces vinyl chloride manufacture.

There will be a quiz on this reading which will consist of 5 multiple choice questions and you will be given 5 minutes to complete the quiz. You will only get one attempt to complete the quiz and it should be completed before our CHBE 243 tutorial on Wednesday at 3pm. I recommend you read the article and then have it for reference with you when completing the quiz. The quiz should be completed individually with no assistance from others.

Once you complete the quiz the answers will not be shown.

CHBE 243 Preparedness Quiz

Q1: What is one of the most commonly manufactured products from vinyl chloride?
a hydrochloric acid
b polyethylene
c polystyrene
d polyvinyl chloride

Q2: What is a common byproduct of vinyl chloride manufacturing?
a hydrochloric acid (HCl)
b sodium chloride (NaCl)
c carbon monoxide (CO)
d polypropylene

Q3: What is one negative issue noted with the reaction pathway of "direct chlorination of ethylene"?
a dangerously high pressures
b need for expensive catalyst
c large amounts of byproduct
d environmental concerns

Q4: The chemical reaction pathway of "thermal cracking of dichloroethane from the chlorination of ethylene" involves how many reaction steps?
a 3
b 4
c 1
d 2

Q5: What is one favourable element noted for the reaction pathway of the "balanced process for chlorination of ethylene"?
a high yield
b safe and easily controlled reactions
c low cost catalyst
d converting both chlorine atoms to vinyl chloride

CHBE 243 Design Exercise Worksheet

CHBE 243: Introduction to Chemical Engineering Process and Technology
Department of Chemical and Biological Engineering
The University of British Columbia

CHBE 243 Design Exercise 1 Worksheet, Group # ____________

Student name: ___________________________________ Student ID : _______________________________

Student name: ___________________________________ Student ID : _______________________________

Student name: ___________________________________ Student ID : _______________________________

Student name: ___________________________________ Student ID : _______________________________

Student name: ___________________________________ Student ID : _______________________________

Student name: ___________________________________ Student ID : _______________________________

We read about five different reaction pathways that were found from literature (patents, scientific articles, etc.) to produce 800 million pounds per year of vinyl monomer. Brainstorm what factors we might consider to start narrowing down this selection of reaction pathways to the most promising of these pathways.

The following are the five reaction pathways, assumed costs of chemical purchased or sold in bulk quantities for the plant, as well as relevant physical properties. Can we use this information to narrow our selection of the reaction pathways? By the end of this session I want you to decide which reaction pathways we should continue to investigate as we move forward and provide evidence as to why?

Reaction Pathway 1 – Direct Chlorination of ethylene

$$C_2H_4 + Cl_2 \rightarrow C_2H_3Cl + HCl$$

Reaction Pathway 2 – Hydrochlorination of acetylene

$$C_2H_2 + HCl \rightarrow C_2H_3Cl$$

Reaction Pathway 3 – Thermal cracking of dichloroethane from chlorination of ethylene

Reaction 1: $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$
Reaction 2: $C_2H_4Cl_2 \rightarrow C_2H_3Cl + HCl$

Overall: $C_2H_4 + Cl_2 \rightarrow C_2H_3Cl + HCl$

Reaction Pathway 4 – Thermal cracking of dichloroethane from oxychlorination of ethylene

Reaction 1: $C_2H_4 + 2\ HCl + \frac{1}{2}\ O_2 \rightarrow C_2H_4Cl_2 + H_2O$
Reaction 2: $C_2H_4Cl_2 \rightarrow C_2H_3Cl + HCl$

Overall: $C_2H_4 + HCl + \frac{1}{2}\ O_2 \rightarrow C_2H_3Cl + H_2O$

Reaction Pathway 5 – Balanced process for clorination of ethylene

Reaction 1: $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$
Reaction 2: $C_2H_4 + 2\ HCl + \frac{1}{2}\ O_2 \rightarrow C_2H_4Cl_2 + H_2O$
Reaction 3: $2\ C_2H_4Cl_2 \rightarrow 2\ C_2H_3Cl + 2\ HCl$

Overall: $2\ C_2H_4 + Cl_2 + \frac{1}{2}\ O_2 \rightarrow 2\ C_2H_3Cl + H_2O$

Compound	Formula	MW (g/mol)	Price (cents/lb)
ethylene	C_2H_4	28.05	30
Acetylene	C_2H_2	26.04	80
Chlorine	Cl_2	70.91	18
Vinyl Chloride	C_2H_3Cl	62.50	35
Hydrogen Chloride	HCl	36.46	25
Water	H_2O	18.02	0
Oxygen (Air)	O_2	32.00	0

CHBE 376 Worksheet

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA
Chemical & Biological Engineering
Faculty of Applied Science

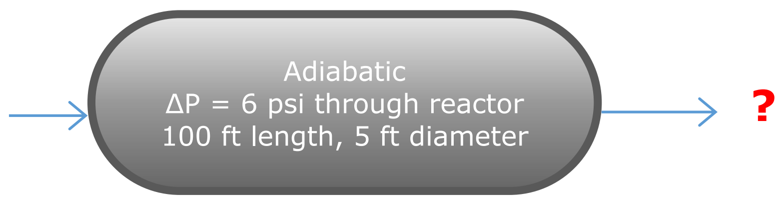
CHBE 376: Computer Flowsheeting
B9 – RPlug and Design Spec

Name: ______________________ **Name:** ______________________

Using the bkp file of Ex. 8 from the reactors section plot the temperature, pressure and composition profiles along a PFR reactor for the conditions listed below.

500 psia / 1268 °F

Toluene	365.6 lbmol/hr
Hydrogen	4661.4
Methane	1773.91



Temperature and pressure profiles (copy these from Aspen):

Composition profiles (for all components, again copied from Aspen):

What length of reactor leads to 75% conversion of the entering toluene?

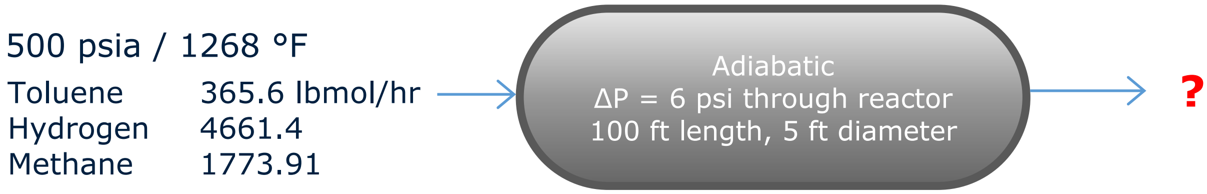
Why is this reactor length different from the length obtained using example 9 from class?

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA
Chemical & Biological Engineering
Faculty of Applied Science

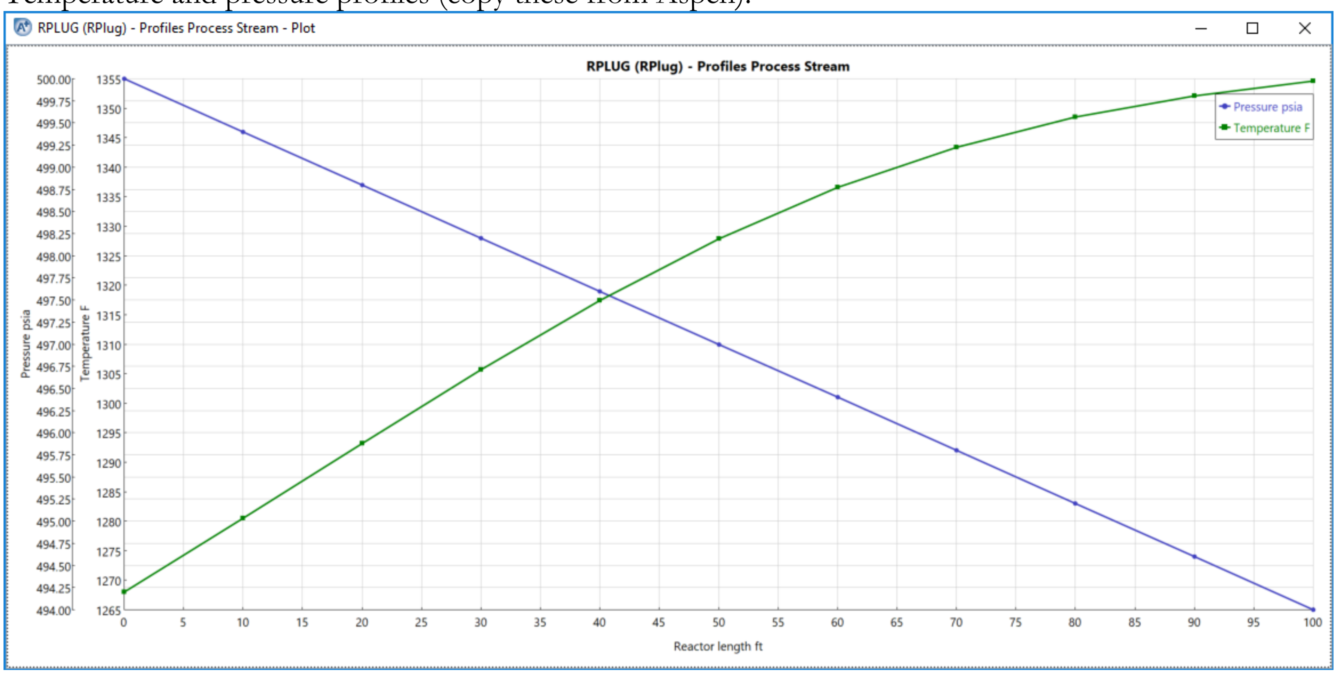
CHBE 376: Computer Flowsheeting
B9 – RPlug and Design Spec

Name: ______________________ **Name:** ______________________

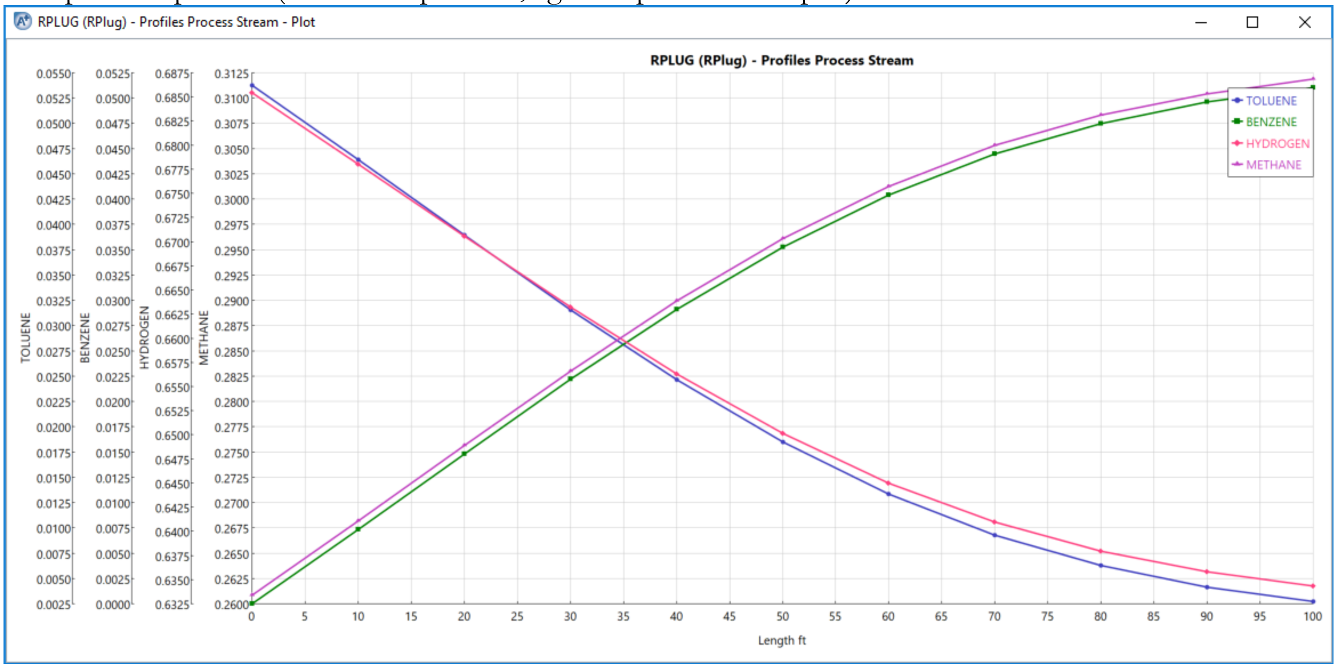
Using the bkp file of Ex. 8 from the reactors section plot the temperature, pressure and composition profiles along a PFR reactor for the conditions listed below.



Temperature and pressure profiles (copy these from Aspen):



Composition profiles (for all components, again copied from Aspen):



What length of reactor leads to 75% conversion of the entering toluene?

59.2 ft

Why is this reactor length different from the length obtained using example 9 from class?

Reactor is now adiabatic (leading to higher temperatures) and a higher reaction rate, so a smaller reactor length is required for the same conversion.
Pressure may also have some effect, as we are at a higher pressure at the start of the reactor, but kinetics are not very affected by this, temperature is a much stronger effect, so that should be the primary reason mentioned for this change.

A.6. Static CHBE Curriculum Map

Click on a course node on the image, or select a course below

- All Courses
- apsc100
- engl112
- phys157
- apsc160
- math100
- chem154
- apsc101
- math101
- phys158
- phys159
- math152
- phys170
- chbe263
- chbe220
- chem250
- chem260
- math253
- chbe241
- chbe201
- chbe221
- chbe244
- chbe230
- chbe251
- chbe264
- math256
- chbe346
- chbe344
- chbe351
- chbe373
- stat251
- chbe362
- apsc278
- chbe376
- chbe355
- chbe356
- chbe345
- chbe365
- chbe381
- chbe366
- chbe456
- chbe485
- chbe481
- chbe474
- chbe464
- chbe457
- chbe453
- chbe454
- chbe459
- apsc450