ABET
Self-Study Report

for the

Chemical Engineering Program

at

University of Maryland Baltimore County

Baltimore, MD

June 30, 2017

CONFIDENTIAL

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BACKGROUND INFORMATION

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B. Program History

The Department of Chemical and Biochemical Engineering (CBE) was founded in 1983 and first offered the Bachelor of Science in Chemical Engineering degree in 1985. Due to its focus in biochemical and biomedical engineering and the interests and projected career paths of many of its students, the Department added a new “Biotechnology and Bioengineering” track in 2001. The first students graduated from the new track in 2004. In March 2011, the Department of Chemical and Biochemical Engineering merged with the Department of Civil and Environmental Engineering to form a new entity, the Department of Chemical, Biochemical and Environmental Engineering (CBEE). As part of the merger, a new “Environmental Engineering and Sustainability” track was developed in Spring 2011, approved by the institutional governance processes in May 2011, and initiated in Fall 2011. The first students graduated from this track in 2014. The number of graduates in each track from the time period of 2012-2017 are presented in Table C-1.

C. Options

The Chemical, Biochemical and Environmental Engineering Department offers a Bachelor of Science in Chemical Engineering (BSChE) degree program. The Department also offers the following graduate degrees: (1) the Master of Science in Chemical and Biochemical Engineering (CBE); (2) the Doctor of Philosophy in Chemical and Biochemical Engineering; (3) the Master of Science in Environmental Engineering (EE); and (4) the Doctor of Philosophy in

Environmental Engineering. In Fall 2015 the department approved a single common set of rules and guidelines that students need to follow in the CBE and EE degree programs.

Academic Year	Traditional	Biotechnol./ Bioeng.	Environ./ Sustain.	Total
2011-12	18	12	0	30
2012-13	19	17	0	36
2013-14	22	6	1	29
2014-15	30	15	1	46
2015-16	30	14	9	53
2016-17	34	15	6	55

Table C-1: Students Graduated From Each Program Track During 2012-17.

The BSChE program consists of three different tracks. The “traditional” track requires 129 credits and is appropriate for students who desire a general background in chemical engineering. The “biotechnology and bioengineering” track requires 133 credits and is appropriate for students who are specifically interested in careers or graduate study in the biochemical or biomedical engineering areas. The “environmental engineering and sustainability” track requires 129 credits and is appropriate for students specifically interested in careers or graduate study in environmental engineering. Students in the undergraduate BSChE program who meet the admission requirements of the department’s graduate program have the option of enrolling in the combined BS/MS program. Students enrolled in this program who take courses according to the prescribed schedule are able to obtain both their accredited BS degree and their MS degree after five years of full-time study.

D. Program Delivery Modes

The BSChE program is a traditional, full-time student program that includes both lecture and laboratory components. Classes are held during the day and early evening hours. Although the department does not have a traditional industrial co-op program, many students are able to obtain a comparable experience in industry or in departmental research laboratories during the summer.

E. Program Locations

The BSChE program is offered exclusively on the main UMBC campus in Baltimore (Catonsville), MD.

F. Public Disclosure

Information on program educational objectives and student outcomes is located at the following internet link: http://cbee.umbc.edu/

G. Deficiencies, Weaknesses or Concerns from Previous Evaluation(s) and the Actions Taken to Address Them

The BSChE program was last reviewed by ABET in AY 2011-12. As a result of this review, the program was granted a full six-year accreditation renewal effective thru AY 2017-18 with no deficiencies, weaknesses or concerns.

GENERAL CRITERIA

CRITERION 1: STUDENTS

UMBC policies related to student admission, transfer student admission, and student educational requirements are contained in the UMBC Undergraduate Catalog, which is available online at http://catalog.umbc.edu/ and is included as a PDF in this submission. Automated enforcement of quantitative credit hour and required course loads, as well as prerequisite enforcement and tracking, is provided by the online Student Accounts (SA) service provided through PeopleSoft software. SA also includes automated tracking of students' degree requirements through the Degree Audit system.

1.A Student Admissions

The B.S. in Chemical Engineering is structured as a two-phase major: students begin as Pre-Chemical Engineering majors, then move into the Chemical Engineering major when they have passed a set of gateway requirements. This section describes the processes of admission to both the Pre-Chemical Engineering and the Chemical Engineering majors.

Students are admitted to UMBC centrally through the Admissions Office, based on a combination of high school GPA, standardized test scores, the strength of the curriculum taken, class rank, other achievements, and an application essay. For the entering freshman class in Fall 2016, the average high school GPA was 3.75, and the average 2-part SAT score was 1216. Freshmen are expected to have completed four years of English, four years of mathematics through Algebra II, three years of science, three years of social science, and two years of a foreign language. Students are required to submit SAT I or ACT scores and a high school transcript, and may optionally submit two letters of recommendation.

Once admitted to UMBC, students are required to take a UMBC-administered math placement exam, a web-based adaptive test designed to identify a student's math readiness.[1] The College of Engineering and Information Technology (COEIT) works with the Provost's Office to determine the eligibility of admitted freshmen to enter our accredited engineering and computing degree programs based on their math placement score. Students who place into MATH 151 (Calculus I) or higher are deemed math-ready for the Chemical Engineering major, and may begin to enroll in the appropriate classes to work towards completion of the gateway and entrance into the Chemical Engineering major. Students who place into MATH 150 (Pre-Calculus) or lower are not considered to be math-ready, and are placed into the Undergraduate Studies (undecided) major. Students who place into MATH 150 are advised by COEIT advisors, and can transfer into the Pre-Chemical Engineering major after passing MATH 150 with a grade of C or higher. Students who place into MATH 106 (Algebra and Elementary Functions) or below are also placed into the Undergraduate Studies major, but are advised centrally through

[1] Students may "challenge" or retake the placement test twice. Students who submit official AP or IB exam scores, or who have transfer credit from courses taken at a community college, may qualify for a placement testing exemption, and receive the appropriate math placement based on their submitted exam scores.

the Provost's office. This differential advising assignment was designed based on an analysis of historical evidence showing that students placing into MATH 106 have a very low probability of continuing successfully in the Chemical Engineering major.

Students are admitted to the chemical engineering program only when they pass all four of the following gateway courses: ENES 101 (Introduction to Engineering), MATH 152 (Calculus and Analytic Geometry II), CHEM 102 (Principles of Chemistry II), and ENCH 215 (Chemical Engineering Analysis) with a grade of at least two B's and two C's. When admitted students must select a track to complete, i.e., either the Traditional track, the Biotechnology and Bioengineering track, or the Environmental Engineering and Sustainability track.

If a student is using AP credit for MATH 152 or Project Lead the Way (PLTW) test credit for ENES 101, then the requirement for admission is at least two B's and one C for the remaining gateway courses. If a student has both AP credit for MATH 152 and PLTW test credit, then the requirement is at least one B and one C for the remaining gateway courses.

At UMBC, students may not register for a course more than two times. They are considered registered for a course if they are enrolled after the end of the schedule adjustment period. A course in which the student receives a grade of "W" (withdraw) is counted as an attempt. Enrolling in a gateway course at UMBC or a Chemical Engineering Department approved equivalent course at another institution is considered an attempt. Chemical Engineering does not allow third attempts in any required course unless extenuating circumstances exist. Students may submit a petition to the CBEE Undergraduate Committee if a third attempt for a course is desired. The committee members will evaluate the petition and vote on the request. Petitions must be submitted using the UMBC Undergraduate Academic Policy Exception Request Form.

1.B Evaluating Student Performance

UMBC students are evaluated using the following grading scale per university policy. The following letter symbols are posted to the permanent record: "A" indicates superior achievement (4 quality points); "B", good performance (3 quality points); "C", adequate performance (2 quality points); "D", minimal acceptable achievement (1 quality point); "F", failure (0 quality points); "I", incomplete work; "W" indicates a course dropped after the end of the fourth week of the semester. "NA" (non-applicable) denotes a course that does not apply to the degree program and does not enter in the GPA (grade point average) calculations. Multiplying the credit value of each course by the numerical equivalent of each grade and then dividing the total quantity of points by the total credit hours attempted determines the semester grade point average. The same method is used to compute cumulative grade point averages. Transfer courses completed at other institutions including other University System of Maryland campuses (with the exception of courses completed through inter-institutional registration), courses passed under the pass/fail option, zero-credit courses, grades earned for campus administered credit-by-examination, incomplete courses and courses repeated for a higher grade are listed on the permanent record but are not included in the grade point average.

Students are able to view their progress through the chemical engineering degree program by using their myUMBC Student Account (SA) Degree Audit function. This system is available to students, advisors and the Undergraduate Program Director via a web-based login, and provides information for both the general university requirements and the degree program requirements.

The myUMBC SA system automatically checks to ensure that students are currently enrolled in required pre-requisite or co-requisite courses, prior to being allowed to register for a course. However, as discussed below, the chemical engineering advisors withhold registration permission for chemical engineering courses with pre-requisites that a student desires to enroll in until after the final grades are posted. After the grades are posted each semester, the advisors look at each advisee's transcript, and if the advisee has completed the pre-requisite courses with a grade of "C" or better they give registration permission for the desired chemical engineering courses.

1.C Transfer Students and Transfer Courses

Transfer applicants are evaluated by UMBC's Admissions Committee based on their academic record at the previous institution(s). Grade point average, strength of curriculum and performance on courses related to the applicant's intended area of study are considered. Applicants must be in good standing at the institution from which they seek to transfer. Applicants with fewer than 30 college credits also are evaluated based on their high school transcript and SAT or ACT scores.

UMBC grants transfer credits for academic courses taken at institutions of higher education accredited by the Regional Association of Colleges and Schools, Commission on Higher Education, in subject areas that are considered part of the student's university program in which he or she has earned a grade of "C" or better. Students can consult the ARTSYS (Articulation System for Maryland College and Universities http://artweb.usmd.edu/) to determine course equivalencies for courses taken at Maryland public institutions.

A student may transfer a maximum of 90 credits from all previous four-year institutions toward a UMBC undergraduate degree. For engineering majors, a maximum of 65 credits are transferable from a two-year program or institution. UMBC's graduation policy stipulates that the final 30 hours toward a bachelor's degree must be completed on campus. The Registrar's Office may approve a request to complete a maximum of two courses within the final 30 credits at another institution.

The CBEE Department performs its own evaluation of acceptable transfer of chemical engineering courses and Introductory Engineering Science (ENES 101) taken at other institutions. The request for this evaluation is made by the student via the Registrar's office using the memorandum shown in Figure 1C-1. This memorandum and any supporting documentation is sent to the CBEE Undergraduate Program Director. These evaluations are performed by the COEIT or CBEE academic advisors in conjunction with the faculty member who teaches the specific course. The CBEE Department also monitors the progress of all transfer students in our engineering courses, to ensure student success.

UMBC has also entered into an articulation agreement with several local high schools to provide teacher training, course curriculum, design project requirements, homework, quizzes and exams, so that the equivalent of ENES 101 can be taught in the high school setting. Students who successfully complete these high school courses and the co-requisites with an A or B grade are eligible to receive ENES 101 credit by exam after they successfully complete 12 credits at UMBC with a minimum 2.5 GPA.

The Maryland State Department of Education asked UMBC to be the university affiliate for Project Lead the Way (PLTW), a four-year high school engineering program. Since 2003 UMBC has provided teacher and counselor training, high school accreditation, AP-like course credit and community college articulations. The PLTW Affiliate Director is Dr. Anne Spence, who is a Professor of the Practice in the UMBC Mechanical Engineering Department. High school students who successfully complete the sequence of four to five PLTW courses (with a grade of A or B, a passing grade on the national exam for each course, and submission of their PLTW portfolio) and the co-requisite math and science courses (with a grade of A or B) are eligible to receive credit for ENES 101 after they successfully complete 12 credits at UMBC with a minimum 2.5 GPA.

1.D Advising and Career Guidance

The first experience incoming students have with advising and learning about UMBC's academic requirements is during Course Selection Day, which is held on various dates over the summer (similar sessions are held over the winter break for students that begin their studies at UMBC in the spring semester). The Course Selection Day program has been enhanced to include "Enrollment 101/301" sessions that prepare students for advising, registration and a review of academic requirements; "University 101/301" sessions focus on academic expectations and academic integrity, and an orientation to Blackboard; "LIFE 101/301" sessions concentrate on the UMBC community and values which emphasize our commitment to civility; and "Advising and Registration 101/301". During the advising and registration session, students meet individually with an advisor in their chosen major.

Incoming students also receive an Advising and Registration guide to help them navigate through the academic requirements. By using their myUMBC Student Account (SA), they can view the Degree Audit Information, which is used as an advising guide for the completion of their major and General Education Program (GEP) requirements. During the advising and registration session on Course Selection Day each student selects their courses and registers for their first semester at UMBC.

Once students are on campus, they are advised according to their declared major. UMBC's COEIT has made a commitment to professional advising for undergraduate students by providing three full-time professional advisors to serve students in Computer Science, Chemical, Biochemical, and Environmental Engineering, Computer Engineering and Mechanical Engineering. These advisors also participate in the freshman/transfer orientation (Course Selection Day) advising process. The advisors have regular walk-in hours, and they also meet with students by appointment. These advisors primarily advise new students for each of the respective programs until the students complete the gateway requirements for each of the programs.

Students are admitted to the chemical engineering program only when they pass all four of the Gateway courses (ENES 101, MATH 152, CHEM 102, and ENCH 215) with grades of at least two B's and two C's. The gateway application, which is completed by the COEIT advisors for chemical engineering students, is shown in Figure 1D-1. After the fulfillment of the gateway requirement, students are assigned to faculty academic advisors within the CBEE Department. Currently these advisors are Dr. Blaney, Dr. Castellanos, Dr. Frey, Dr. Leach, Dr. Raikar, and Dr. Reed. The students are assigned such that there is balance based on faculty members' overall workload. Although advising by faculty members within the CBEE Department is split between six faculty members, special advising situations are discussed with the Undergraduate Program Director and the CBEE Chair. When students petition the department for special consideration and exceptions, the Undergraduate Committee meets to discuss and vote on any relevant petitions.

Students must see their advisors at least once a semester to be cleared for registration. During the advising session, students are given electronic advisement verification so that they can register for the upcoming semester. They are also given permission to register for CBEE courses for which they have completed the pre-requisites. However, the advisors withhold registration permission for chemical engineering courses with pre-requisites that the students are currently enrolled in until after the final grades are posted. The advisors then give the registration permission (prior to the start of the next semester) to students who have completed the prerequisite courses with a "C" or better. This process ensures that each of the CBEE students have completed all of the pre-requisites for required courses. In addition, in the transitions from Pre-Chemical Engineering to Chemical Engineering, after CBEE students successfully complete ENCH 215 (Chemical Engineering Analysis), the UPD goes through the records of each student to ensure they have completed the gateway. After this process, the UPD then gives the students registration permissions for ENCH 225L (Chemical Engineering Problem Solving and Experiment Design Lab), the sophomore course for the Chemical Engineering Department. That same semester, the students are assigned to their advisors who go through the records for each student to ensure that they are planning to take, are currently registered for, or have completed the required math and chemistry classes. This ensures that the students will be ready to take their junior level courses (ENCH 300: Thermodynamics and ENCH 425: Transport Phenomena I, Fluid Mechanics).

Each student's advising file contains a copy of the Chemical Engineering Program Course Guide (see Figure 1D-2 for Traditional Track, Figure 1D-3 for Biotechnology and Bioengineering Track, and Figure 1D-4 for Environmental and Sustainability Track). The advisors update this guide prior to each advising appointment. Advising notes are also recorded online at the end of each advising session. During the spring and summer of 2015 the Undergraduate Committee developed strategies to maintain a personalized advising experience while working with a greater number of students. In the fall semester of 2015 the undergraduate academic advisors met twice with the entire CBEE student body. In the first of these meetings, the advisors presented advising information (reminders, expectations, etc.) and gave out a set of instructions for students to follow in order when they sign up for advising appointments. The

Undergraduate Committee also developed an Advising Worksheet (see Figure 1D-5) which permits students to conduct a degree audit, and which needs to be filled out before a student is permitted to sign up for an advising meeting. In the second of these meetings, the academic advisors checked the student forms, and if students complied with all instructions, they were able to sign up for an appointment. In the 2016 Fall Semester, the advising worksheet was implemented as a google.xls document to ease the process; students are required to bring the completed document to their advising appointment.

Students are encouraged to see their advisors on a regular basis. They are also informed of the various programs and services that provide additional support for student success. One of these services is the Learning Resource Center (LRC) that provides free learning assistance services that help students fulfill their goals for an undergraduate education. The LRC provides tutoring for most 100 and 200 level courses, and provides small group tutoring in the Math Lab, the Writing Center and the English Language Center. In addition, the Chemistry Tutorial Center is staffed by a full-time chemistry instructor and 30 advanced undergraduate students, who provide free tutoring for freshman and sophomore chemistry courses.

The Learning Resource Center sends requests to all faculty members with first-semester freshman in their classes to gather information on the progress of freshman students. Emails are then sent to all first-year students (including transfer students) who are in danger of receiving D's and F's in particular courses. It is then the student's responsibility to follow up and seek guidance from their advisor, their mentor, or from another resource on campus. The faculty members of these students also contact them and provide guidance on how to improve their standing in the class. The CBEE Department has also adopted this program. Instructors in the core chemical engineering classes (ENCH 215 Chemical Engineering Analysis, ENCH 225 Chemical Engineering Problem Solving and Experimental Design, ENCH 300 Thermodynamics, ENCH 425 Transport Phenomena I, Fluid Mechanics, ENCH 427 Heat and Mass Transfer, and ENCH 440 Kinetics) develop a list of students who are in danger of receiving D's and F's and emails are automatically generated alerting the student to their academic situation.

Many of the CBEE students at UMBC are involved in various other programs, such as athletic programs, the Meyerhoff Scholars program, the Center for Women and Information Technology (CWIT) Scholars program, and the Honors College Scholars program. These programs also provide advising and mentoring. Student athletes normally meet with a staff member from the Academic Center for Student-Athletes, in addition to their academic advisor. Before registration, all student-athletes are required to submit their intended schedule of athletic events to their CBEE advisor for approval. The Meyerhoff Scholars program is intended for students who are committed to promoting minority careers in science, mathematics and engineering. These students are paired with a mentor in their area of interest and participate in a wide range of academic and cultural enrichment activities. Meyerhoff students are advised by the Meyerhoff program as well as by an academic advisor within the CBEE Department. The CWIT Scholars program provides mentoring and support to high-achieving entering freshmen that are committed to promoting women in computer science, information technology and engineering.

According to UMBC policy, all undergraduates with a cumulative grade point average of 2.0 or above are academically eligible to return for a subsequent semester. All first-semester freshmen that earn less than a 2.0 cumulative GPA are considered to be in “academic jeopardy” and are notified of this by letter. Students in academic jeopardy may enroll for the subsequent semester, but are required to participate in intensive advising, counseling or tutoring activities. There is no notation of academic jeopardy placed in their permanent record. All students who are not first-semester freshmen, and who do not meet the minimum cumulative GPA standards outlined below (Table 1.D-1), will be placed on academic probation. Following the first occurrence of academic probation, if at any future time a student again does not meet the minimum cumulative standards the student will receive an academic suspension from the University for a minimum of the next regular semester. The determination of probation, suspension or dismissal is made at the end of each regular semester and is noted on the official and permanent record.

Students on academic suspension who attend another institution and complete 12 academic credits with a GPA of 2.5 or above will be reinstated to UMBC upon receipt of an application for reinstatement. Students on academic suspension who do not meet these conditions will be required to file a formal petition for reinstatement, which must include a comprehensive plan for attaining good academic standing within a year. Reinstatement is not guaranteed. Students who have been reinstated and who do not meet the minimum cumulative GPA standards after one year will be dismissed and, in general, will not be considered for future re-instatement.

Attempted Credits	Minimum Cumulative GPA
0-14	1.25
15-44	1.50
45-74	1.75
75-89	1.95
90-120	2.00

Table 1.D-1: Cumulative GPA Standards.

Several of the forms used in the advising processes are shown in the Figures 1.D-1 to 1.D-6 given below.

Gateway Cleared: ________
System: ________
ENGL 100: ________
Letter Sent: ________
File to Department: ________

CHEMICAL ENGINEERING MAJORS

NEW GATEWAY – EFFECTIVE FALL 13

Name:
ID#:
Address:

Students are admitted to the chemical engineering program only when they pass all four of the following Gateway courses: ENES 101, MATH 152, CHEM 102, and ENCH 215 with a grade of at least two B's and two C's.* Enrolling in a gateway course at UMBC or a Chemical Engineering Department pre-approved equivalent course at another institution is considered an attempt.

Course	Grade Earned
MATH 152 Calculus and Analytic Geometry II	
ENES 101 Introductory Engineering Science	
CHEM 102 Principles of Chemistry II	
ENCH 215 Chemical Engineering Analysis	

*If a student is using AP credit for MATH 152 or PLTW credit for ENES 101, then the requirement is at least two B's and one C. If the student has both MATH 152 and PLTW test credit, then the requirement is at least one B and one C.

Figure 1.D-1. Gateway application for the Chemical Engineering Program

UMBC CHEMICAL ENGINEERING PROGRAM
Traditional Track Course Guide

NAME: ______________________

USER ID#: ______________________

Effective Date: Spring 2013

Minimum Academic Credits - 129

MATHEMATICS

COURSE	CR	GRADE	REMARKS
MATH 151	4		
MATH 152	4		
MATH 251	4		
MATH 225	3		
TOTAL:	15 cr hours		

BASIC SCIENCE

COURSE	CR	GRADE	REMARKS
CHEM 101	4		
CHEM 102	4		
CHEM 102L	2		
PHYS 121	4		
PHYS 122	4		
TOTAL	18 cr hours		

ADVANCED CHEMISTRY

COURSE	CR	GRADE	REMARKS
CHEM 351	3		
CHEM 351L	2		
CHEM 301	4		
CHEM 302	3		
CHEM 311L	3		
ELECTIVE[1]	3		
TOTAL:	18 cr hours		

1. Advanced Chemistry or Mathematics Electives include: CHEM 300, 352, MATH 221, 301, 404 and STAT 355.

GENERAL EDUCATION REQUIREMENTS (GEP)

AREA	COURSE	CR	GRADE	REMARKS
	ENGL 100	3		
AH				
AH				
AH				
SS				
SS				
SS				
L 201 lev				
C or L				
TOTAL		28 cr hours		

PHYSICAL EDUCATION REQUIREMENTS

AREA	COURSE	CR	GRADE	REMARKS
PE				
PE				

CHEMICAL ENGINEERING AND UNIVERSITY REQUIREMENTS

Math & Basic Sciences	33 cr hours
Advanced Chemistry & Math	18 cr hours
Gen. Ed. Requirements	28 cr hours
Physical Education	(3 cr hours)
Engineering Courses	50 cr hours
Total	129 cr hours

ENGINEERING PROFESSIONAL COURSES

COURSE	CR	GRADE	REMARKS
ENES 101	3		
ENME 110	3		
ENCH 215	3		
ENCH 225	4		
ENCH 300	3		
ENCH 425	3		
ENCH 427	3		
ENCH 437L	3		
ENCH 440	3		
ENCH 442	3		
ENCH 444	3		
ENCH 445	3		
ENCH 446	4		
TOTAL:	41 cr hours		

CHEMICAL ENGINEERING ELECTIVES*

COURSE	CR	GRADE	REMARKS
TOTAL:	9 cr hours		

*Chosen from ENCH 450, ENCH 459, ENCH 468, ENCH 482, ENCH 484, ENCH 484, ENCH 489.

Figure 1.D-2. Traditional track course guide for the Chemical Engineering Program.

UMBC CHEMICAL ENGINEERING PROGRAM
Bioengineering Track Course Guide

NAME: ______________________
USER ID#: ______________________

Effective Date: Spring 2013
Minimum Academic Credits - 133

MATHEMATICS

COURSE	CR	GRADE	REMARKS
MATH 151	4		
MATH 152	4		
MATH 251	4		
MATH 225	3		
TOTAL:	15 cr hours		

BASIC SCIENCE

COURSE	CR	GRADE	REMARKS
CHEM 101	4		
CHEM 102	4		
CHEM 102L	2		
PHYS 121	4		
PHYS 122	4		
TOTAL	18 cr hours		

ADVANCED CHEMISTRY

COURSE	CR	GRADE	REMARKS
CHEM 303	3		
CHEM 351	3		
CHEM 352	3		
CHEM 437	4		
TOTAL:	13 cr hours		

BIOLOGY

COURSE	CR	GRADE	REMARKS
BIOL 141	4		
BIOL 302	4		
BIOL 303	3		
TOTAL:	11 cr hours		

GENERAL EDUCATION REQUIREMENTS (GEP)

AREA	COURSE	CR	GRADE	REMARKS
	ENGL 100	3		
AH				
AH				
AH				
SS				
SS				
SS				
L 201 lev				
C or L				
TOTAL	28 cr hours			

PHYSICAL EDUCATION REQUIREMENTS

AREA	COURSE	CR	GRADE	REMARKS
PE				
PE				

CHEMICAL AND BIOCHEMICAL ENGINEERING AND UNIVERSITY REQUIREMENTS

Math & Basic Sciences	33 cr hours
Advanced Chemistry	13 cr hours
Biology	11 cr hours
Gen. Ed. Requirements	28 cr hours
Physical Education	(3 cr hours)
Engineering Courses	42 cr hours
Bioengineering Electives	6 cr hours
Total	133 cr hours

ENGINEERING PROFESSIONAL COURSES

COURSE	CR	GRADE	REMARKS
ENES 101	3		
ENCH 215	3		
ENCH 225	4		
ENCH 300	3		
ENCH 425	3		
ENCH 427	3		
ENCH 440	3		
ENCH 442	3		
ENCH 444	3		
ENCH 445	3		
ENCH 446	4		
ENCH 482	3		
ENCH 485L	4		
TOTAL:	42 cr hours		

BIOTECHNOLOGY/BIOENGINEERING ELECTIVES*

COURSE	CR	GRADE	REMARKS
TOTAL:	6 cr hours		

*Chosen from ENCH 456, ENCH 468, ENCH 484, ENCH 486, ENCH 489, ENCH 660, ENCH 662, ENCH 664, or ENCH 666
(only one of the ENCH 660-666 courses)

Figure 1.D-3. Biotechnology and bioengineering track course guide for the Chemical Engineering Program.

UMBC CHEMICAL ENGINEERING PROGRAM
Environmental Engineering & Sustainability Track Course Guide

NAME: ____________________
USER ID#: ____________________

Effective Date: Spring 2013
Academic Credits -129

MATHEMATICS

COURSE	CR	GRADE	REMARKS
MATH 151	4		
MATH 152	4		
MATH 251	4		
MATH 225	3		

TOTAL: 15 cr hours

BASIC SCIENCE

COURSE	CR	GRADE	REMARKS
CHEM 101	4		
CHEM 102	4		
CHEM 102L	2		
PHYS 121	4		
PHYS 122	4		

TOTAL 18 cr hours

ADVANCED CHEMISTRY

COURSE	CR	GRADE	REMARKS
CHEM 351	3		
CHEM 352	3		
CHEM 303	3		
ENCH 210 or ELECTIVE[1]	3		

TOTAL: 12 cr hours

1. Advanced Chemistry or Mathematics Electives include: CHEM 300, 437, MATH 221, 301, 404 and STAT 355.

GENERAL EDUCATION REQUIREMENTS (GEP)

AREA	COURSE	CR	GRADE	REMARKS
	ENGL 100	3		
AH				
AH				
AH				
SS				
SS				
SS				
L 201 lev				
C or L				

TOTAL 28 cr hours

PHYSICAL EDUCATION REQUIREMENTS

AREA	COURSE	CR	GRADE	REMARKS
PE				
PE				

CHEMICAL ENGINEERING AND UNIVERSITY REQUIREMENTS

Math & Basic Sciences	33 cr hours
Advanced Chemistry & Math	12 cr hours
Gen. Ed. Requirements	28 cr hours
Physical Education	(3 cr hours)
Engineering Courses	56 cr hours
Total	129 cr hours

ENGINEERING PROFESSIONAL COURSES

COURSE	CR	GRADE	REMARKS
ENES 101	3		
ENME 110	3		
ENCH 215	3		
ENCH 225	4		
ENCH 300	3		
ENCH 310	3		
ENCH 412	3		
ENCH 414	3		
ENCH 425	3		
ENCH 427	3		
ENCH 437L	3		
ENCH 440	3		
ENCH 442	3		
ENCH 444	3		
ENCH 445	3		
ENCH 446	4		

TOTAL: 50 cr hours

CHEMICAL ENGINEERING ELECTIVES*

COURSE	CR	GRADE	REMARKS

TOTAL: 6 cr hours

*Chosen from ENCH 450, ENCH 459, ENCH 468, ENCH 470, ENCH 482, ENCH 484, ENCH 489.

Figure 1.D-4. Environmental and sustainability track course guide for the Chemical Engineering Program.

Bachelor of Science in Chemical Engineering - Advisement Worksheet

Name:	ID:	Track:

Degree Audit Information						
120 credits	2.00 GPA	45 UPLE	WI	PHED	PHED	ENGL 100
AH	AH	AH	SS	SS	SS	Math
Science	Science	Lab	Culture	201 Language	HS level IV	Proficiency MLLI
MATH 151 152 251 225		ENES 101			Technical Writing	
CHEM 101 102 102L PHYS 121 122			ENCH 215 225L 300 425 427 440 442 444 445 446			

Traditional Track	Bioengineering Track	Environmental Track
CHEM 351 351L 301 311L 302 Ad Elect	CHEM 351 352 437 303	CHEM 351 352 303 ENCH 210*
ENME 110	BIOL 141 302 303 ENCH 482	ENME 110 ENCH 310 412 414
ENCH 437L Elective Elective Elective	ENCH 485L Elective Elective	ENCH 437L Elective Elective
Review the repeat policy.		

Current Schedule (please list anticipated grade)	Summer / Winter Courses	Spring/Fall Courses

I am aware that providing false or misleading information in regard to my academic progress (e.g.courses completed, course descriptions, grades earned) will result in a referral to the Office of Student Judicial Programs.

Student Signature: Date:

Advisor Signature: Date:

Figure 1.D-5. Advising worksheet for the Chemical Engineering Program.

UMBC

AN HONORS UNIVERSITY IN MARYLAND

PHONE: 410-455-3637
FAX: 410-455-1141
VOICE/TTY: 410-455-3233

DATE:
TO: Articulation Chair/Coordinator of
FROM: Ciera Clay, Academic Program Evaluator
RE: Evaluation of Transfer Course

Attached please find a course description for your review. Please evaluate the course in terms of general transfer credit or major/minor program requirements. Please feel free to contact me at extension 52630 with any questions or concerns.

Your assistance in completing and returning this course evaluation by ________ is sincerely appreciated. Thank you in advance.

Name: **myUMBC Username:** **Major:** **Minor:**

Evaluation Requested:

Please Check Here if Syllabus or Course Outline is Needed before evaluation below can be completed.												
Institution: United Kingdom				*Please check or enter code for all appropriate responses.*								
Semester YYYY02 - Spring YYYY09 – Fall	**Course Number**	**Title of Course**	**Credit**	**Transfer as Elective**	**Major Req.**	**Minor Req.**	**Gen Ed**		**Physical Education**	**Upper Level Credit**	**Transfer as a Direct Equivalent** (list UMBC Course)	
							GFR	**GEP**				

This course is not acceptable for transfer credit because:

Comments:

*** Evaluator Signature:* ______________________ | *Print Name:* ______________________ | *DEPT:* ____________ | *Date:* ________________

Gen Ed Codes:	GFR	AH Arts & Humanities	SS Social Science	M Math	BPS Biological/ Physical Science (non-lab requirement)	BPSLAB Biological/ Physical Science (lecture & lab requirement)	LAB Biological/ Physical Science (lab requirement)	201L 201-level foreign language	L Language (other than 201 proficiency requirement)	C Culture	EN English Composition
	GEP	AH Arts & Humanities	SS Social Science	M Math	S Biological/ Physical Science (non-lab requirement)	SL Biological/ Physical Science (lecture & lab requirement)	LAB Biological/ Physical Science (lab requirement)	201L 201-level foreign language		C Culture	EN English Composition

Figure 1.D-6 Transfer memorandum for course articulation

1.E Work in Lieu of Courses

1.E.1 Advanced Placement, College Level Examination Program, and International Baccalaureate Program

Credits earned through Advanced Placement (AP) College Level Examination Program (CLEP) or International Baccalaureate (IB) may be used to fulfill General Education Requirements, when equivalent to a UMBC general education course. Each academic department determines which credits earned through AP, CLEP, or IB may be applied to major requirements. Credits earned through AP, CLEP, and IB tests have no effect on the calculation of the UMBC grade point average, nor are they applied to the minimum number of credits needed to qualify for honors at graduation. A list of examinations, scores, credits and course equivalency can be found at: http://catalog.umbc.edu/content.php?catoid=15&navoid=768

1.E.2 Internships

The Career Center at UMBC can assist students in their internship searches in UMBCworks. The opportunities there are specifically posted by employers who know the value of a talented UMBC student. Students are encouraged to cast a wide net and apply to multiple opportunities that they are interested in and qualified for. Students can use the "Where to Find Internships and Jobs" section to identify other sources or the "Create Your Own Internship" section in UMBCworks.

1.E.3 Military Service

Physical Education Courses: Students must pass two activity courses in physical education. Military (active duty, veteran, reservist), may seek an exemption from this requirement through the Physical Education department. UMBC students participating in the ROTC program are eligible to receive physical education credit by completing PHED 175.

1.F Graduation Requirements

1.F.1 Minimum University Requirements for an Undergraduate Baccalaureate Degree

Minimum Academic Credits: Students must complete a minimum of 120 academic credits to receive a UMBC degree. Academic credits exclude developmental level coursework and physical-activity courses.

Minimum Grade Point Average: Students must have a minimum cumulative UMBC grade point average (GPA) of 2.0 to receive a UMBC degree. The UMBC GPA excludes LRC, ELC, pre-college-level coursework, physical-activity courses when a grade of "P" is earned, and academic courses taken as P/F earned with a "P."

Minimum Upper Level Credits: At least 45 of the minimum 120 credits required for graduation must be in UMBC courses numbered at the 300-level or above, or their equivalents.

Minimum Resident Credits: Students must complete at least 30 credits of course work at UMBC (referred to as resident credit) to receive a UMBC degree. Of the 30 resident credits, 15 must be upper-level (courses numbered at the 300-level or above).

Writing Intensive Course (WI): Students must complete one writing-intensive course; a designated WI course may count for the major or a general education requirement, or it may be taken as an elective. The WI course must be completed at UMBC; transfer courses may not to be used to fulfill this requirement.

Physical Education Courses: Students must pass two activity courses in physical education. Credit for physical education courses is considered institutional credit; as such, the credits do not count toward the 120 academic credits required for graduation.

1.F.2 General Education Requirements

Recommended competency areas for General Education Programs have been established by the Middle States Commission on Higher Education and adopted by the Maryland Higher Education Commission.

UMBC's general education requirements enable students to develop functional skills and competencies important for academic and lifetime success which include the following areas: written and oral communication, scientific and quantitative reasoning, critical analysis and reasoning, technological competency and information literacy.

- Students must complete all general education requirements with a grade of "C" or better.
- Courses taken on a Pass/Fail basis may not be applied toward general education requirements.

To fulfill the general education requirements, UMBC students will complete courses distributed across six broad areas of academic inquiry:

English Composition (ENGL 100): Students must complete one English composition course with a general education designation within the first 30 credit hours of enrollment at UMBC.

Mathematics: Students must complete one mathematics or statistics course with a general education designation within the first 30 credit hours of enrollment at UMBC.

Arts and Humanities: Students must complete three arts and humanities courses with a general education designation; courses must come from at least two different academic disciplines.

Social Sciences: Students must complete three social science courses with a general education designation; courses must come from at least two different academic disciplines.

Sciences: Students must complete two science courses and one laboratory course with a general education designation.

Language and Culture: Students must complete foreign language through the 201 level or demonstrated proficiency at that level; B.A. students must also complete two culture courses with a general education designation; B.S. students must also complete one culture course with a general education designation.

1.F.3 Graduation Application

Undergraduate students within two semesters (90 or more credits) of completing their degree requirements are eligible to apply for graduation. To apply for graduation, students access the online Undergraduate Diploma Application located on myUMBC under the "Topics" tab, then select Classes and Grades. A myUMBC username and password are needed to access and complete the Undergraduate Diploma Application. Both the academic department and the Registrar's Office conduct a review for each candidate's status towards completion of the degree requirements. Students may see their status at any time using the Degree Audit tool in myUMBC. All majors, minors, and certificate requirements are reviewed, as well as the general education requirements. Candidates are notified by mail of their graduation status mid-semester.

Undergraduates must apply for graduation through myUMBC by the following dates:

- For May Graduation – February 15
- For August Graduation – June 15
- For December Graduation – September 15

During the advising session each semester, the CBEE Department advisors review the progress that each advisee is making toward the completion of their chemical engineering degree. In addition to the math, science and engineering requirements, the general university requirements are also reviewed with each student. Students are able to view their Degree Audit information (for both the general university requirements and the degree program requirements) with the myUMBC Student Account Information. When students apply for graduation the advisors receive Department Graduation Review forms to verify that the math, science and engineering course requirements have been met. The Registrar's office provides the graduation review for the GEP requirements.

1.G Transcripts of Recent Graduates

Transcripts for recent graduates along with advising notes and information on how to interpret the transcripts will be provided as requested by the ABET team chair.

CRITERION 2: PROGRAM EDUCATIONAL OBJECTIVES

2.A UMBC Mission Statement

2.A.1 University Mission

UMBC is a dynamic public research university integrating teaching, research and service to benefit the citizens of Maryland. As an Honors University, the campus offers academically talented students a strong undergraduate liberal arts foundation that prepares them for graduate and professional study, entry into the workforce, and community service and leadership. UMBC emphasizes science, engineering, information technology, human services and public policy at the graduate level. UMBC contributes to the economic development of the State and the region through entrepreneurial initiatives, workforce training, K-16 partnerships, and technology commercialization in collaboration with public agencies and the corporate community. UMBC is dedicated to cultural and ethnic diversity, social responsibility and lifelong learning.

The UMBC mission statement is located at the following link: http://about.umbc.edu

2.A.2 University Vision

UMBC: An Honors University in Maryland seeks to become the best public research university of our size by combining the traditions of the liberal arts academy, the creative intensity of the research university, and the social responsibility of the public university. We will be known for integrating research, teaching and learning, and civic engagement so that each advances the others for the benefit of society.

2.A.3 COEIT Strategic Goals

Provide a Distinctive Undergraduate Experience - Strengthen UMBC's performance as a research university that integrates a high-quality undergraduate education with faculty scholarship and research through a distinctive curriculum and set of experiences promoting student engagement, such as seminars, study groups, research opportunities, mentoring, advising, co-curricular learning experiences and exposure to diversity.

Continue to Build Research and Graduate Education - Pursue growth in PhD's granted, faculty awards, publications, scholarly activities, creative achievements, and research grants and contracts in order to strengthen the culture of UMBC as a research university and continue to rank in a prestigious cohort of research universities.

2.B Program Educational Objectives

The Chemical, Biochemical and Environmental Engineering faculty, in consultation with program constituencies (see below), has established the Program Educational Objectives described below. These broad statements describe what our graduates are expected to attain within a few years of graduation and are based on the needs of our constituencies. To make them easier to remember, we call them mnemonically the "Five Cs". According to the "Five Cs," within three to five years after graduation the following should apply:

C1. Graduates will have demonstrated **Competency in the Discipline** of chemical engineering.

C2. Graduates will have exhibited **Critical Thinking Ability** that has enabled them to solve complex problems.

C3. Graduates will have successfully achieved **Cooperative Goals through Teamwork**.

C4. Graduates will have demonstrated effective **Communication**.

C5. Graduates will have exhibited the **Capacity for Life-long Learning**.

These program educational objectives are publicly displayed outside the main departmental office (ENG 314) and published on the departmental website at the following link: http://cbee.umbc.edu/academics/abet-accreditation/

2.C Consistency of the Program Educational Objectives with the Mission of the Institution

Our program educational objectives and UMBC's mission statement are complementary and reinforce each other. In developing our program educational objectives, we sought guidance from our constituents and have included aspects distinctive to our university and our college. The UMBC mission specifically supports a strong undergraduate liberal arts foundation that prepares graduates for professional study, entry into the workforce, and leadership. We believe the skills and behaviors included in our program educational objectives together with the general education program at UMBC will prepare students for a career in chemical engineering and beyond since the emphasis is on life skills, not merely competency in the discipline of chemical engineering. The UMBC mission also explicitly highlights science, engineering and lifelong learning consistent with the departmental program educational objectives.

2.D Program Constituencies

In order to develop our program educational objectives and continuously improve our program, we seek input from our various constituencies whom we have defined as follows:

1. The CBEE Advisory Board, consisting of leaders in industry and academia in Maryland and neighboring states who understand the unique challenges and opportunities associated with educating students to serve local industry and graduate education needs

2. Employers who hire, and graduate programs who enroll, our students

3. Alumni

4. Faculty

5. Current students

6. The UMBC College of Engineering and Information Technology (UMBC COEIT)

The CBEE program educational objectives were developed to meet the needs of the constituencies listed above. Each of the "Five Cs" targets a specific competency identified as critical by all constituencies. Due to rapid changes in science, technology, information access and business models, our program educational objectives target skill sets that will allow our graduates to be flexible and successful in a multitude of settings.

The CBEE advisory board members include representatives from industry, governmental agencies, and academic institutions, some of whom are alumni of our undergraduate and graduate programs. A full list of board members is displayed publically at the following link: http://cbee.umbc.edu/advisory-board/

2.E Process for Review of the Program Educational Objectives

2.E.1 General Procedures

Our program educational objectives were originally developed in 2003 through a series of meetings of CBEE faculty, and informal communication with alumni, current students, industrial employers and other chemical engineering departments. The program educational objectives were approved by the entire CBEE Department in December, 2003. In 2004, the CBEE Advisory Board was constituted, and its members unanimously endorsed the program educational objectives as written. Since 2004, the program educational objectives have been reviewed and revised as necessary according to the timeline shown in Table 2.E.1-1 below.

Activity	**Academic Year**							
	Year 5 RC-5 2010-11	**Year 6 RC-5 2011-12**	**Year 1 RC-6 2012-13**	**Year 2 RC-6 2013-14**	**Year 3 RC-6 2014-15**	**Year 4 RC-6 2015-16**	**Year 5 RC-6 2016-17**	**Year 6 RC-6 2017-18**
Alumni Surveys	X						X	
CBE Advisory Board Input	X						X	
College of Engineering and IT Input	X	X					X	X
Department Input and Review of Findings	X	X					X	X
Feedback from ABET Review		X						X
Revision (if necessary)		X						X
	Report Preparation	**Review Year**					**Report Preparation**	**Review Year**

Table 2.E.1-1: Timeline for Review and Revision of Program Educational Objectives During Current and Previous Review Cycles. RC-5 denotes the 2006-12 ABET review cycle (the fifth cycle since the CBEE Department was founded) and RC-6 denotes the 2012-18 ABET review cycle (the sixth review cycle since the CBEE Department was founded).

It was decided during the 2016-17 academic year that the timeline shown in Table 2.E.1-1 needed to include more activity throughout each review cycle in order to ensure that the program educational objectives remain as relevant as possible. Consequently, starting in the 2018-19 academic year, the revised timeline shown in Table 2.E.1-2 will be followed.

Activity	**Academic Year**							
	Year 5 RC-6 2016-17	**Year 6 RC-6 2017-18**	**Year 1 RC-7 2018-19**	**Year 2 RC-7 2019-20**	**Year 3 RC-7 2020-21**	**Year 4 RC-7 2021-22**	**Year 5 RC-7 2022-23**	**Year 6 RC-7 2023-24**
Alumni Surveys	X			X			X	
CBE Advisory Board Input	X			X			X	
College of Engineering and IT Input	X			X			X	
Current undergraduate student input	X			X			X	
Departmental Input and Review of Findings	X	X		X	X		X	X
Feedback from ABET Review		X						X
Revision (if necessary)		X			X			X
	Report Preparation	**Review Year**					**Report Preparation**	**Review Year**

Table 2.E.1-2: Revised Timeline for Review and Revision of Program Educational Objectives which will Apply for Future Review Cycles. RC-6 denotes the 2012-18 ABET review cycle (the sixth review cycle since the CBEE Department was founded) and RC-7 denotes the 2018-24 ABET review cycle (the seventh and next review cycle since the CBEE Department was founded)

As shown in Table 2.E.1-2, starting from the 2016-17 academic year the program educational objectives will be reviewed and revised in a more holistic and continuous way as compared to the previous method. For example, input will be solicited from alumni using surveys sent triennially to the subgroup of alumni that are 3-5 years past graduation. These surveys will solicit both the opinions of alumni on the suitability of the program educational objectives and information on alumni achievements that will put these opinions in context. As also shown in the table, input concerning the relevancy of the program educational objectives will be solicited on a three year cycle from the CBEE Advisory Board, departmental faculty, current undergraduate students (which includes the current president of the undergraduate AIChE student chapter), and the COEIT Advisory Board. After considering input from these sources, the departmental faculty will decide whether revisions to the program educational objectives are needed, also on a three-year cycle.

Brief details of the items shown for 2016-17 academic year (i.e., year 5 of review cycle 6) in Table 2.E.1-2 are as follows:

- The COEIT Advisory Board met on Sept. 23, 2016, and the CBEE Program Educational Objectives were reviewed.
- A survey of alumni opinions on the program educational objectives was completed on May 2, 2017.
- Selected senior undergraduate students met as a focus group to discuss the program educational objectives on May 17, 2017. Opinions of the focus group were transmitted to the CBEE Advisory Board meeting on May 19, 2017.
- The CBEE Advisory Board met on May 19, 2017, and the CBEE program educational objectives were discussed and reviewed. Four graduating seniors were present at the meeting and participated in the review.
- A CBEE departmental faculty meeting was held on May 24, 2017, and several modifications to the current program educational objectives were proposed. These proposed modifications will be finalized during the 2017-18 academic year according to the timeline shown in Table 2.E-2.

2.E.2 Survey of Alumni Opinions Concerning PEOs

As mentioned in the previous section, one aspect of the process for reviewing the program educational objectives includes a periodic survey of departmental alumni who are 3-5 years past their graduation date, i.e., alumni who have graduated in the time period 2011-13 in the present case. The goal of this survey is to obtain opinions of alumni concerning the importance of the existing program educational objectives and information on the basis for these opinions. Basic information concerning the alumni survey conducted during 2017 is as follows:

- Total number of BS degrees awarded 2011-2013: 104
- Number of valid alumni email addresses: 103
- Number of alumni survey responses: 18
- Response rate for alumni survey: 17%

The results of the alumni survey from 2017 are summarized below. Table 2.E.2-3 specifically summarizes the opinions of the alumni concerning the importance of the program educational objectives. As indicated by the averages shown, the alumni considered the objectives to vary from being very important to being important. Furthermore, the three most important of the five objectives were considered to be CBEE Objective C2 (Critical thinking), CBEE Objective C3 (Cooperative goals through teamwork) and CBEE Objective C4 (Communication).

Objective	Very unimportant 1	Very important 2	Neither important nor unimportant 3	Important 4	Very important 5	Average ± 95% CI
C1	0	0	6	6	6	4.0 ± 0.4
C2	0	0	0	5	13	4.7 ± 0.2
C3	0	0	1	7	10	4.5 ± 0.3
C4	0	0	0	5	13	4.7 ± 0.2
C5	0	0	5	7	6	4.1 ± 0.4

Table 2.E.2-3. Alumni survey results indicating importance of the Program Educational Objectives to the success of our graduates.

In order determine the extent to which the opinions in Table 2.E.2-3 are based on actual experience, the alumni were asked to assess whether they had an opportunity in their professional work to demonstrate each objective. Alumni were also asked to provide examples of these opportunities. The results obtained are summarized in Table 2.E.2-4. As shown, the surveyed alumni felt they had significant direct experience on which to base their opinions, with the possible exception of CBEE Objective C5 (Capacity for life-long learning) where the average score representing the extent of opportunities is 3.7/5.0. The final column in Table 2.E.2-4 gives the average number of opportunities for demonstrating the objectives reported by the alumni. This average number was determined by taking the total number of example opportunities provided by the alumni and then dividing by the number of alumni giving responses. As shown, the number of opportunities per alumnus varied from 4 to 6 for the objectives, which gives a further indication that the opinions of the alumni given in Table 2.E.2-3 are based on actual experiences. Additional survey details, including a full list of opportunities to achieve the objectives being considered reported by the alumni, are available in the departmental ABET folder on the Google Drive.

Opportunity to Demonstrate Objective							
Objective	**Not at all 1**	**Very little 2**	**Somewhat 3**	**Much 4**	**A great deal 5**	**Average ± 95% CI**	**Average opportunities per alumnus**
C1	0	0	5	8	5	4.0 ± 0.4	4
C2	0	0	2	8	8	4.3 ± 0.3	4
C3	0	0	1	8	9	4.4 ± 0.3	5
C4	0	0	2	7	9	4.4 ± 0.3	5
C5	0	1	6	8	3	3.7 ± 0.4	6

Table 2.E.2-4. Alumni survey results indicating whether graduates had an opportunity to demonstrate each CBEE Program Educational Objective.

2.E.3 Revisions During Current Review Cycle

The following activities and decisions related to revision of Program Educational Objectives have been implemented since last general ABET review:

Summer 2012: No changes needed to the program educational objectives based on ABET and Advisory Board recommendations.

Spring 2017: Based on the review process described in this section, several minor revisions to the CBEE Program Educational Objectives were proposed at a faculty meeting on May 23, 2017. As indicated in Table 2.E.1-2, these proposed revisions will be finalized during the summer of 2018. These proposed revisions can be summarized as follows (note that deletions are denoted with crossed-out text and additions are denoted by underlined text in red):

Within 3-5 years after graduation:

C1. Graduates will have Competency in the Practice of Chemical Engineering.

C2. Graduates will have Critical Thinking Ability that will enable them to solve complex engineering or related technical problems.

C3. Graduates will have the ability to work in Cooperation with Diverse Teammates.

C4. Graduates will be effective Communicators.

C5. Graduates will have demonstrated their Commitment to Life-long Learning.

CRITERION 3: STUDENT OUTCOMES

The CBEE Student Outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge, and behaviors that students acquire as they progress through the program. The CBEE Student Outcomes were developed in consultation with program constituencies to support our Program Educational Objectives (i.e., the “Five Cs”). Thus the two are closely linked as shown in Section 3.B presented below. The student outcomes are publicly displayed outside the main CBEE departmental office (ENG 314). CBEE course syllabi list all student outcomes targeted by the course. Student outcomes are reviewed by the CBEE Undergraduate Committee and, if major changes are proposed, the full faculty meet to discuss and vote on the changes. Note that minor changes from year to year concerning how each student outcome is assessed in individual courses are documented in footnotes to Table 4.A.1-1 in Section 4.A.1. An example of a minor assessment change would be changing from using homework problem sets to examination questions.

3.A Student Outcomes

All specific program criteria are encompassed in CBEE Student Outcomes C1.1-C5.4. Table 3.A-1 gives a mapping of the CBEE Student Outcomes C1.1-C5.4 to the ABET Student Outcomes (a-k). The 18 CBEE Student Outcomes are as follows:

Student Outcome C1.1: Have a Foundation in Math and Science
Students will be able to apply knowledge in mathematics and science.

Student Outcome C1.2: Demonstrate Proficiency in Chemical Engineering Principles
Students will have proficiency in and be able to apply core chemical engineering principles.

Student Outcome C1.3: Design Processes
Students will be able to design a system, component, or processes using chemical engineering principles to meet desired needs within realistic constraints.

Student Outcome C1.4: Use Modern Tools
Students will be able to use the techniques, skills and modern engineering tools (including computational, programming/modeling) necessary for the practice of chemical or biochemical engineering.

Student Outcome C1.5: Understand Broader Impact
Students will have an elementary knowledge of the contemporary issues including an understanding of professional and ethical responsibility, sustainability, health & safety and the impact of engineering solutions in a global, economic, environmental and societal context.

Student Outcome C2.1: Solve Open-Ended Problems
Students will be able to analyze/solve open-ended problems in chemical engineering.

Student Outcome C2.2: Evaluate Solutions/Designs

Students will be able to evaluate solutions or designs given realistic constraints (economic or otherwise).

Student Outcome C2.3: Design and Conduct Experiments
Students will be able to design and conduct experiments in order to obtain appropriate data for evaluation of an engineering problem.

Student Outcome C2.4: Analyze Data
Students will be able to analyze and interpret data in order to solve engineering problems.

Student Outcome C3.1: Work Effectively in Teams
Students will be able to work effectively in teams with others having different backgrounds.

Student Outcome C3.2: Fill Various Roles
Students will be able to fill both leadership and supporting roles in a team.

Student Outcome C3.3: Resolve Conflict
Students will be able to define rules for conflict resolution and practice those rules.

Student Outcome C4.1: Communicate in Writing
Students will be able to communicate effectively in written form.

Student Outcome C4.2: Communicate Orally
Students will be able to communicate effectively in oral form.

Student Outcome C5.1: Define Problems
Students will be able to identify and define a problem given an open-ended question or situation.

Student Outcome C5.2: Locate Information
Students will have the ability to locate tools and information relevant to a problem.

Student Outcome C5.3: Assimilate Information
Students will have the ability to assimilate information relevant to a problem.

Student Outcome C5.4: Self-Assessment
Students will be able to assess their own ability/knowledge to solve a problem and know when to seek help.

Student Outcome	ABET Criterion 3 *										
	a	b	c	d	e	f	g	h	i	j	k
C1.1 Foundation Math/Sciences	X										
C1.2 Prof. Chem. Eng. Principles	X				X						
C1.3 Design Processes			X								
C1.4 Use Modern Tools											X
C1.5 Broader Impact						X		X		X	
C2.1 Open-Ended Problems					X						
C2.2 Evaluate Solutions/Designs			X					X			
C2.3 Design Experiments		X									
C2.4 Analyze Data		X									
C3.1 Work Effectively in Teams				X							
C3.2 Fill Various Roles				X							
C3.3 Resolve Conflict				X							
C4.1 Communicate in Writing							X				
C4.2 Communicate Orally							X				
C5.1 Define Problems					X				X		
C5.2 Locate Information					X				X		
C5.3 Assimilate Information					X				X		
C5.4 Self-Assessment					X				X		

* (a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 3.A-1: Relationship between CBEE student outcomes and ABET Criterion 3: Student Outcomes/Program Criteria (*i.e.*, ABET student outcomes (a-k)).

3.B Relationship of Student Outcomes to Program Educational Objectives

The CBEE Student Outcomes and Program Educational Objectives are closely linked. In essence, the student outcomes define the set of learning outcomes representing knowledge, skills and behaviors students should possess by the time of graduation in order to achieve the program educational objectives within three to five years after graduation. To make the connection between the two clear, we have classified our student outcomes with respect to the program educational objectives as shown below.

C1. Within three to five years after graduation, graduates will have demonstrated **<u>Competency in the Discipline</u>** of chemical engineering.

In order to meet Program Educational Objective C1, students are expected to have the following knowledge, skills, or behaviors at the time of graduation:

Student Outcome C1.1: Have a Foundation in Math/Sciences
Students will be able to apply knowledge in mathematics and science

Student Outcome C1.2: Demonstrate Proficiency in Chemical Engineering Principles
Students will have proficiency in and be able to apply core chemical engineering principles.

Student Outcome C1.3: Design Processes
Students will be able to design a system, component, or processes using chemical engineering principles to meet desired needs within realistic constraints.

Student Outcome C1.4: Use Modern Tools
Students will be able to use the techniques, skills and modern engineering tools (including computational, programming/modeling) necessary for the practice of chemical or biochemical engineering.

Student Outcome C1.5: Understand Broader Impact
Students will have an elementary knowledge of the contemporary issues including an understanding of professional and ethical responsibility, sustainability, health and safety and the impact of engineering solutions in a global, economic, environmental and societal context.

C2. Within three to five years after graduation, graduates will have exhibited **<u>Critical Thinking Ability</u>** that has enabled them to solve complex problems.

In order to meet Program Educational Objective C2, students are expected to have the following knowledge, skills, or behaviors at the time of graduation:

Student Outcome C2.1: Solve Open-Ended Problems
Students will be able to analyze/solve open-ended problems in chemical engineering.

Student Outcome C2.2: Evaluate Solutions/Designs
Students will be able to evaluate solutions or designs given realistic constraints (economic or otherwise).

Student Outcome C2.3: Design and Conduct Experiments
Students will be able to design and conduct experiments in order to obtain appropriate data for evaluation of an engineering problem.

Student Outcome C2.4: Analyze Data
Students will be able to analyze and interpret data in order to solve engineering problems.

C3. Within three to five years after graduation, graduates will have successfully achieved **Cooperative Goals through Teamwork**.

In order to meet Program Educational Objective C3, students are expected to have the following knowledge, skills, or behaviors at the time of graduation:

Student Outcome C3.1: Work Effectively in Teams
Students will be able to work effectively in teams with others having different backgrounds.

Student Outcome C3.2: Fill Various Roles
Students will be able to fill both leadership and supporting roles in a team.

Student Outcome C3.3: Resolve Conflict
Students will be able to define rules for conflict resolution and practice those rules.

C4. Within three to five years after graduation Graduates will have demonstrated effective **Communication**.

In order to meet Program Educational Objective C4, students are expected to have the following knowledge, skills, or behaviors at the time of graduation:

Student Outcome C4.1: Communicate in Writing
Students will be able to communicate effectively in written form.

Student Outcome C4.2: Communicate Orally
Students will be able to communicate effectively in oral form.

C5. Within three to five years after graduation, graduates will have exhibited the **Capacity for Life-long Learning**.

In order to meet Program Educational Objective C5, students are expected to have the following knowledge, skills, or behaviors at the time of graduation:

Student Outcome C5.1: Define Problems
Students will be able to identify and define a problem given an open-ended question or situation.

Student Outcome C5.2: Locate Information
Students will have the ability to locate tools and information relevant to a problem.

Student Outcome C5.3: Assimilate Information
Students will have the ability to assimilate information relevant to a problem.

Student Outcome C5.4: Self-Assessment
Students will be able to assess their own ability/knowledge to solve a problem and know when to seek help.

CRITERION 4: CONTINUOUS IMPROVEMENT

4.A. Student Outcomes

4.A.1. Listing and Description of Assessment Processes Used

A variety of assessment processes are used to gather data in order to evaluate the achievement of each student outcome. The assessment processes include both direct and indirect measures of outcome achievement. Each of these processes is described in detail below. Assessment processes are designated as **(DA)** for direct assessments and **(IDA)** for indirect assessments. All assessment instruments, rubrics, data and analyzed results are posted to the appropriate subfolders in the departmental main ABET folder on Google Drive.

1. Direct Assessment of Student Outcome Achievement (DA) – Performed Each Semester

In order to directly assess achievement of student outcomes, each outcome is measured in a variety of required courses in the curriculum. Table 4.A.1-1 below lists student outcomes and designates which required courses and assignments will be used for direct assessment of outcome achievement. At the end of each semester, the instructors of the courses indicated in Table 4.A.1-1 create a Direct Assessment Document according to a standard template that is shown in Section 4.C. Goals for outcome attainment are described later in this section, and rubrics used for direct assessment are given in Section 4.C.

2. Exit Interviews (IDA) – Performed Yearly

At the end of each spring semester, all students taking the capstone senior design course (ENCH 446: Process Engineering Economics and Design II) are invited to meet one-on-one with a faculty member for an exit interview. All full-time faculty members participate in this process. The exit interview provides students personal attention and allows them to share concerns or comments confidentially. The questions used in the exit interview as well as compiled results will be available for evaluation during the ABET accreditation visit in printed form and in the departmental ABET folder on Google Drive.

3. Focus Group Discussions (IDA) – Performed Yearly

A focus group discussion is conducted at the end of each spring semester and all students enrolled in the second semester capstone senior design course (ENCH 446: Process Engineering Economics and Design II) are required to participate. A faculty member is present and participates in the focus group discussion. In most cases a single question is posed to the focus group. The question generally targets a specific area in which we desire additional information or perspective that is not easily gained through other means. The topics discussed and student opinions are transcribed into a document, and the set of documents produced during the current review cycle will be available for evaluation during the ABET visit.

4. Senior Survey (IDA) – Performed Yearly

All students taking the capstone senior design course (ENCH 446: Process Engineering Economics and Design II) are asked to complete a questionnaire late in the spring semester. This document includes a set of standard questions that are answered on a scale of 1 to 5 (1 = poor, 5 = excellent) plus space for written comments. Although the questions are not directly based on the student outcomes, all are related to one or more of these outcomes. A copy of the survey instrument and summary of the results and comments will be available for evaluation at the time of the ABET visit. The average scores on all standard questions from each year are examined by the Undergraduate Program Director, and the areas with the lowest scores are identified. The summarized results will be available for evaluation during the ABET accreditation visit in printed form and in the departmental ABET folder on Google Drive.

Table 4.A.1-1 illustrates the items used in each course to perform direct assessments of student outcomes. Note that the student outcomes assessed by the indirect assessment methods described above have varied substantially from year to year during the current review cycle, and therefore these indirect assessments have not been entered into Table 4.A.1-1.

Student Outcome	**CBEE Course**											
	215	**225**	**300**	**425**	**427**	**437L**	**440**	**442**	**444**	**445**	**446**	**485L**
C1.1 Foundation Math/Sciences	**F**			**E/F**			**E**	**E**		**E/HW[5]**		
C1.2 Prof. Chem. Eng. Principles	**E/F**		**E/F**	**E/F**	**E/F**		**E**					
C1.3 Design Processes			**E[1]**				**E**		**P**	**HW**	**P**	
C1.4 Use Modern Tools	**P**	**E**				**LR**		**P[2]**		**HW**	**P**	**LR**
C1.5 Broader Impact		**HW**			**P**	**LR**		**P[2]**			**P**	**LR**
C2.1 Open-Ended Problems		**LR**	**P[3]**	**P[4]**				**P[2]**			**P**	
C2.2 Evaluate Solutions/Designs			**P[3]**					**P[2]**	**P**		**P**	
C2.3 Design Experiments		**LR**		**HW**		**LR**						**LR**
C2.4 Analyze Data		**E**				**LR**	**HW/ E**					**LR**
C3.1 Work Effectively in Teams		**S**				**OBS**					**S/OBS**	**OBS**
C3.2 Fill Various Roles		**S**				**OBS**					**S/OBS**	**OBS**
C3.3 Resolve Conflict		**S**				**OBS**					**S/OBS**	**OBS**
C4.1 Communicate in Writing		**LR**			**P**	**LR**						**LR**
C4.2 Communicate Orally					**P[7]**				**P[6]**		**P**	
C5.1 Define Problems		**LR**							**P**		**OBS**	
C5.2 Locate Information	**P**				**HW**						**P/OBS**	
C5.3 Assimilate Information					**HW**					**HW**	**P**	
C5.4 Self-Assessment		**LR**	**R[4]**						**P**		**S**	

Abbreviations	**History of Changes from Year 1 of 2012-18 Review Cycle (RC-6)**	**Notes**
E = Mid-term Exam/Exam Question F = Final Exam HW = Homework LR = Lab Report P = Project O = Outreach Project OBS = Observation S = Peer evaluation/survey R= Reflections	[1] Changed from HW to Exam in AY 12-13 [2] Added in AY 12-13 [3] Changed from HW to Project in AY 12-13 [4] Added in AY 12-13 [5] Changed from HW to E/HW iv AY 15-16 [6] Eliminated in AY 16-17 [7] Changed from Outreach Project to Project in AY 15-16	I. Observation (OBS) includes observations by faculty of outcomes, such as the ability to work in teams, that are assessed using the rubrics described in Section 4.C.

Table 4.A.1-1: Targeted courses and assignments used for direct assessment of CBEE Student Outcomes for AY2016-17

4.A.2. Frequency of Assessment Processes

As described in Section 4.A.1, at the end of each academic semester of each year, the instructors of the courses shown in Table 4.A.1-1 create a Direct Assessment Document according to a standard template (see Section 4.C). In addition, senior surveys, focus group discussions, and exit interviews are conducted every year with all students taking the second semester capstone senior design course (ENCH 446: Process Engineering Economics and Design II).

4.A.3. Expected Level of Attainment of Each Student Outcome

Direct assessments are employed in our assessment process to better evaluate (in comparison to indirect assessment methods) whether students graduating from the program have attained the CBEE Student Outcomes. This section of this self-study specifies the metrics employed, the broad objectives, and the desired quantitative goals for these direct assessments. Although our analysis is performed for the 18 CBEE Student Outcomes, this self-study section is organized by the ABET Outcomes (a-k) and then cross-referenced by CBEE Student Outcomes to make it easier for an ABET program evaluator to map our processes to the ABET outcomes.

(a) An ability to apply knowledge of mathematics, science, and engineering
ABET Student Outcome (a) is addressed in our program through the CBEE Student Outcomes C1.1 and C1.2. All mathematics, science and engineering courses must be passed with a grade of "C" or better in order meet pre-requisite requirements and move forward in the curriculum. While a grade of "C" or better in all mathematics, science and engineering courses does not guarantee the attainment of this student outcome by students graduating from the program, it greatly reduces the likelihood of a student graduating who is deficient in these skills. To assess the extent to which our students have attained these abilities, we evaluate examination scores in fundamental areas of chemical engineering including Material and Energy Balances, Thermodynamics, Fluid Mechanics, Heat and Mass Transfer, Reaction Kinetics and Reactor Design, and Separation Processes. Each instructor submits the needed scores for evaluation along with a minimum satisfactory level of achievement using a Direct Assessment Document (see Section 4.C). We then calculate the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum). Our goal is to have a value for this metric that is 10% or less in any given academic year. [2]

(b) An ability to design and conduct experiments, as well as to analyze and interpret data

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[2] The 10% target value for determining whether assessments are attained is based on an estimated accuracy for the assessments that can be as large as ±10%, as indicated by the scatter in Figures 4.A-1 to 4.A-4 shown later. Consequently the 10% assessment target value selected here corresponds to the attainment of the minimum possible assessment value accounting for measurement error.

ABET Student Outcome (b) is addressed in our program through CBEE Student Outcomes C2.2 and C2.3. To assess the extent to which our students have attained the ability to design and conduct experiments as well as to analyze and interpret data, we evaluate laboratory report and examination scores in ENCH 225 (Chemical Engineering Problem Solving and Experimental Design) and in the senior-level laboratory courses ENCH 437L and ENCH 485L. Each instructor submits the needed scores for evaluation along with a minimum satisfactory level of achievement using a Direct Assessment Document (see Section 4.C). We then calculate the average percent of students who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum). Our goal is to have a value for this metric that is 10% or less in any given academic year.

(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

ABET Student Outcome (c) is addressed in our program through the CBEE Student Outcomes C1.3 and C2.2. To assess the extent to which our students have attained the ability to design a system, component or process within realistic constraints, we evaluate performance on homework and projects in courses oriented toward design including ENCH 446 (Design II), which is the capstone design course in the curriculum. Each instructor submits the needed scores for evaluation along with a minimum satisfactory level of achievement using a Direct Assessment Document (see Section 4.C). We then calculate the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum). For the particular case of Student Outcome C1.3 a weighting factor is applied to ENCH 446 so that it is weighted more in the average. Our goal is to have a value for this metric that is 10% or less in any given academic year.

(d) An ability to function on multidisciplinary teams

ABET Student Outcome (d) is addressed in our program through the CBEE Student Outcomes C3.1 and C3.3, which define the abilities we and our constituents have identified as critical to teamwork. To assess the extent to which students graduating from our program have attained these abilities, we use a rubric with which to score individuals based on student work, student assessment of group members, and faculty observation (See rubrics in Section 4.C). Our broad objective is for all students in ENCH 446 (Design II, which is the capstone design course in the curriculum) to demonstrate a "satisfactory" level of attainment as defined by the rubric or by a peer assessment method. In more precise terms, our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(e) An ability to identify, formulate, and solve engineering problems

ABET Student Outcome (d) is addressed in our program through the CBEE Student Outcomes C1.2 and C2.1. To assess the extent to which our students have attained the ability to identify, formulate and solve engineering problems, we evaluate performance on homework, examinations, projects and lab reports in courses oriented toward problem-solving. Each instructor submits the needed scores for evaluation along with a minimum satisfactory level of achievement using a Direct Assessment Document (see Section 4.C). We then calculate the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum). Our goal is to have a value for this metric that is 10% or less in any given academic year.

(f) An understanding of professional and ethical responsibility

ABET Student Outcome (f) is addressed in our program through the CBEE Student Outcome C1.5, which define the abilities we and our constituents have identified as critical to broader impact. To assess the extent to which students graduating from our program have attained an understanding of professional and ethical responsibility, we use a rubric with which to score individuals based on student work (see rubrics in Section 4.C). Our broad objective is for all students to demonstrate a "satisfactory" level of attainment as defined by the rubric. In more precise terms our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(g) An ability to communicate effectively

ABET Student Outcome (g) is addressed in our program through the CBEE Student Outcomes 4.1 and 4.2, which define the abilities we and our constituents have identified as critical to effective communication. To assess the extent to which students graduating from our program have attained an ability to communicate effectively through oral presentations, we use a rubric with which to score individuals (see rubrics in Section 4.C). Our broad objective is for all students in ENCH 446 (Design II, which is the capstone course in the curriculum) to demonstrate a "satisfactory" level of attainment as defined by the rubric. To assess the extent to which students graduating from our program have attained an ability to communicate effectively in writing, we evaluate performance on written laboratory reports based on individual writing scores, and again our broad objective is for students to demonstrate a "satisfactory" level of attainment as defined by the rubric. In more precise terms our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

ABET Student Outcome (h) is addressed in our program through the CBEE Student Outcome C1.5, which defines the skills we and our constituents have identified as critical to broader impacts. Students work toward attainment of ABET Student Outcome (h) in large part through the general education requirements necessary for graduation. To assess the extent to which students graduating from our program have attained the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, we use a rubric with which to score individuals based on student work, course completion and extracurricular participation in activities directly related to the Outcome (see rubrics in Section 4.C). Our broad objective is for all students to demonstrate a "satisfactory" level of attainment as defined by the rubric. In more precise terms our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(i) A recognition of the need for, and an ability to engage in life-long learning

ABET Student Outcome (i) is addressed in our program through the CBEE Student Outcomes C5.1 to C5.4, which define the skills we and our constituents have identified as critical to life-long learning. To assess the extent to which students graduating from our program have attained these skills, we use a rubric with which to score individuals based on student work and faculty observation (see rubrics in Section 4.C). Our broad objective is for all students in ENCH 446 (Design II, which is the capstone course in the curriculum) to demonstrate a "satisfactory" level of attainment for each student outcome related to life-long learning as defined by the rubric. In more precise terms our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(j) A knowledge of contemporary issues

ABET Student Outcome (j) is addressed in our program through the CBEE Student Outcome C1.5, which defines the skills we and our constituents have identified as critical to knowledge of contemporary issues. Students work toward attainment of ABET Student Outcome (j) in large part through the general education requirements necessary for graduation. To assess the extent to which students graduating from our program have attained knowledge of contemporary issues, we use a rubric with which to score individuals based on student work and course completion (see rubric in Section 4.C). Our broad objective is for all students to demonstrate a "satisfactory" level of attainment as defined by the rubric. In more precise terms our goal is to have the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum) at the level of 10% or less in any given academic year.

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

ABET Student Outcome (k) is addressed in our program through CBEE Student Outcome C1.4. To assess the extent to which our students have attained the ability to use techniques, skills and modern engineering tools necessary for engineering practice, we evaluate performance on examinations, projects and lab reports focused on specific engineering techniques and tools. Each instructor submits the needed scores for evaluation along with a minimum satisfactory level of achievement using a Direct Assessment Document (see Section 4.C). We then calculate the average percent of students in the assessed courses who fall below the minimum satisfactory performance level while still passing the course (i.e., are completing or moving forward in the curriculum). Our goal is to have a value for this metric that is 10% or less in any given academic year.

As just described, the primary method to evaluate whether a given student outcome has attained its assessment goal in a given academic year is to calculate an overall average result for the assessment. This is accomplished by determining the fraction of students in each course associated with the outcome who fail to satisfy the outcome assessment, but who pass the course, and then averaging this value for all courses in a given academic year according to Table 4.A.1-1 and using weighting factors when applicable. If this average value is greater than 10% then the overall assessment goal is not attained. Furthermore, if the overall assessment goal for an outcome is not attained, especially for multiple successive years, then assessment results are analyzed in more depth to verify the result and determine remedies. For example, assessment results can be analyzed in more depth using alternative weighting factors when calculating averages, including weighting factors that account for recent instructor changes for particular courses. Furthermore, entirely different types of averages can be used, such as averages based on student cohort groups as opposed to academic year. Average assessment results can also be determined individually for the sophomore-, junior-, and senior-level courses associated with an outcome to compare formative (i.e., in progress) assessments with summative (i.e., end of program) assessments.[3] Indirect assessment results can also be used to help confirm deficiencies in the curriculum and to suggest course improvements.

The two-step process for analyzing direct assessment results just described has been selected for several reasons. In particular, the first step of determining an average result is easy to perform and provides a useful "bird's-eye view" of assessment results. Furthermore, the simplicity of the first step helps to provide year-to-year continuity despite faculty turnover or other unanticipated events. The first step is also consistent with the 2011 CBEE ABET self-study document that described the initial implementation direct assessments in the department. Simultaneously, the overall analysis method consisting of the two sequential steps is highly flexible and therefore likely to find useful solutions for curriculum deficiencies. Despite the suitability of the assessment data analysis method just outlined, the CBEE Department is nevertheless committed to the continuous improvement of this method. Consequently, now that a full set of assessment data for a six year review cycle is available, the Department will use this data to investigate improvements to its analysis methods during the early stages of the next ABET review cycle.

4.A.4. Summary of Results of the Direct Assessment Evaluation Process and Analysis of the Extent to which Each Student Outcome is Being Attained.

4.A.4.a Overall Summary

[3] The assessment terminology and methods employed in this section are adapted from *Designing Better Engineering Education through Assessment: A Practical Resource for Faculty and Department Chairs*, J. E Spurlin, S. A. Rajala, and J. P. Lavelle, eds., Stylus Publishing, Sterling, VA, 2008.

The results obtained for the overall outcome assessment (i.e., the average assessment for all pertinent courses in a given year) for all 18 CBEE Student Outcomes are summarized in Tables 4.A.4-2 and 4.A.4-3. Note that Table 4.A.4-2 contains results for outcomes associated with Program Educational Objectives C1 and C2 and Table 4.A.4-3 contains results for outcomes associated with Program Educational Objectives C3, C4, and C5. These two tables therefore provide a concise summary of the extent to which student outcomes are being attained according to the standard set by the CBEE Department throughout the current review cycle.

CBEE Student Outcomes Associated with PEOs C1 and C2	**Academic Year**				
	Year 1 RC-6 2012-13	Year 2 RC-6 2013-14	Year 3 RC-6 2014-15	Year 4 RC-6 2015-16	Year 5 RC-6 2016-17
C1.1 Foundation Math/Sciences	**10**	**9**	**5**	**23**	**10**
C1.2 Proficiency Chemical Engineering Principles	**9**	**9**	**6**	**12**	**9**
C1.3 Design Processes	**10**	**10**	**8**	**12**	**8**
C1.4 Use Modern Tools	**10**	**10**	**10**	**8**	**16**
C1.5 Broader Impacts	**5**	**4**	**4**	**1**	**2**
C2.1 Open ended problems	**3**	**1**	**0**	**3**	**4**
C2.2 Evaluate solutions/design	**19**	**3**	**2**	**1**	**2**
C2.3 Design Experiments	**10**	**17**	**5**	**6**	**8**
C2.4 Analyze Data	**16**	**17**	**10**	**12**	**7**

Table 4.A.4-2: Summary of Overall Direct Assessment Results for 5 Consecutive Years of Program for Student Outcomes Associated with PEOs C1 and C2. Data reported as percent of students who did not pass the direct assessment item but who passed the course averaged over all the applicable courses for a given outcome. A deficiency in achieving an overall yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded).

As shown in Tables 4.A.4-2 and 4.A.4-3, for some outcomes there has been a continual maintenance of satisfactory assessments during the current review cycle, such as for CBEE Student Outcomes C2.1, C3.1, C3.2, C4.1, C4.2 and several others. For other outcomes there are sporadic instances of unsatisfactory outcome assessments, such as for CBEE Student Outcomes C1.1, C1.2, C1.3, C1.5, C2.2, and several others. As shown later, these sporadic results are most likely due to temporary factors such as fluctuations in grading method caused by changes in the instructor for particular courses. For still other outcomes there are unsatisfactory assessments that persist for two or more academic years and that indicate corrective actions are likely required. Two examples in this last category are CBEE Student Outcomes C2.3 and C2.4 where unsatisfactory assessments persisted for more than one consecutive academic year at the beginning of the current review cycle. However, as shown in Table 4.A.4-2, the assessments for Student Outcomes C2.3 and C2.4 are currently trending toward being satisfactory, evidently due to corrective actions that have been taken. Another example in this last category is CBEE Student Outcome C5.3 where unsatisfactory outcomes were observed for the most recent two academic years. CBEE Student Outcome C5.3 will therefore be reviewed during the 2017-18 academic year, and potential program-wide corrective actions considered according to the schedule shown in Section 4.B.2. Consideration of all these different cases indicates to a reasonable degree that the outcome assessments obtained during the current review cycle either are satisfactory, or are trending toward being satisfactory in a reasonable manner, or are in the process of being reviewed if they have recently become unsatisfactory.

CBEE Student Outcomes Associated with PEOs C3, C4, and C5	Academic Year				
	Year 1 RC-6 2012-13	Year 2 RC-6 2013-14	Year 3 RC-6 2014-15	Year 4 RC-6 2015-2016	Year 5 RC-6 2016-17
C3.1 Work effectively in teams	**7**	**3**	**2**	**2**	**0**
C3.2 Fill various roles	**5**	**2**	**1**	**1**	**4**
C3.3 Resolve conflicts	**5**	**4**	**1**	**2**	**3**
C4.1: Communicate in Writing	**6**	**10**	**8**	**0**	**0**
C4.2: Communicate Orally	**4**	**10**	**6**	**0**	**3**
C5.1 Define problems	**2**	**3**	**8**	**9**	**2**
C5.2 Locate information -	**14**	**3**	**4**	**10**	**5**
C5.3 Assimilate information	**7**	**10**	**8**	**14**	**18**
C5.4 Self-Assessment	**14**	**7**	**6**	**7**	**4**

Table 4.A.4-3: Summary of Overall Direct Assessment Results for 5 Consecutive Years of Program for Student Outcomes Associated with PEOs C3, C4, and C5. Data reported as percent of students who did not pass the direct assessment item but who passed the course. A deficiency in achieving an overall yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded).

4.A.4.b Detailed Direct Assessment Analyses for Five Selected CBEE Student Outcomes

As mentioned in Section 4.A.3, the primary metric for evaluating the extent to which an outcome is properly attained is to determine whether the average of the direct assessments for that outcome as defined by Table 4.A.1-1 is below a specified target value. Furthermore, if this metric is not met for a particular outcome, especially for several consecutive years, then program changes are considered in order to remedy the situation. In this context this section gives examples of follow-on analyses of direct assessment results that provide additional information compared to an average assessment and that serve two main purposes as follows: (1) they can be used to investigate in depth the reasons why an outcome assessment has failed to achieve its target and (2) they can be used to suggest remedies in terms of program improvements when assessment targets are not achieved.

Detailed assessment analyses of the type just mentioned are produced by the CBEE ABET Coordinator and presented to the Undergraduate Committee as part of the program continuous improvement procedure described in Section 4.B-2 (see in particular Step 2 of the procedure). The remainder of this section describes examples of detailed direct assessment analyses for five selected student outcomes. Two of these analyses are associated with program improvement efforts while the other three analyses confirm that direct assessment results do not justify a program-wide improvement effort. All of the detailed analyses shown here illustrate how these analyses help to uncover pedagogical trends that are useful when making program improvements, such as the student learning progression from the sophomore year to the senior year or the identification of systematic influences on assessments. Analogous (albeit more subjective) analyses of indirect assessments are presented in Section 4.A.4.c. Full details of direct assessments (i.e., direct assessment results for individual items before they are averaged to obtain the summarized results shown in Tables 4.A.4-2 and 4.A.4-3) are available for all 18 CBEE Student Outcomes in the departmental ABET folder on Google Drive.

In the previous section it was determined that the 18 CBEE Student Outcomes had generally attained satisfactory assessments with the exception of Student Outcomes C2.3 (Design and conduct experiments) and C2.4 (Analyze data), which were initially unsatisfactory but were trending toward being satisfactory during the current review cycle. The confirmation of these improvement trends for these two assessments will therefore be selected as the first two examples of detailed assessment analyses. These two outcomes will also be considered together due to their close relationship.

It can be seen in Table 4.A.1-1 that the courses that are assessed for Student Outcomes C2.3 and C2.4 are ENCH 225(Chemical Engineering Problem Solving and Experimental Design Lab), ENCH 425 (Transport Processes I: Fluids), 437L (Chemical Engineering Laboratory), ENCH 440 (Chemical Engineering Kinetics) and ENCH 485L (Biochemical Engineering Laboratory). Table 4.A.4-4 summarizes details of the courses and assessment methods for these two outcomes. This table also indicates which of the courses considered are taken in the senior year (in which case they can provide summative assessments) and which are taken sophomore or junior years (in which case they can provide formative assessments).

Student Outcome	**Sophomore and Junior Year Courses**			**Senior Year Courses**	
	225L	**425**	**440**	**437L**	**485L**
C2.3 Design and Conduct Experiments	LR	HW		LR	LR
C2.4 Analyze Data	E		HW/E	LR	LR

Table 4.A.4-4: Courses where Assessment Occurs and Assessment Methods Used CBEE Student Outcomes C2.3 and C2.4. LR denotes laboratory report, E denotes examination and HW denotes homework.*

Table 4.A.4-5 shows results from the yearly assessments for CBEE student outcomes C2.3 and C2.4 for the time period 2012-2017. As mentioned above, the assessment goal was considered to be achieved if the value for the overall average assessment was 10% or less, i.e., the percentage of students who did not pass the direct assessment item, but who passed the course, was less 10% or less. For clarity, values in red and in cells with pink shading indicate that this overall assessment goal was not reached, i.e., these values are greater than 10%. Note that ENCH 225 was offered only in the spring semester of the 2012-13 academic year so that the assessment results for this course for the 2012 Fall Semester are missing. In addition, some of the assessment results for ENCH 485L, which is the laboratory course for the biotechnology and

bioengineering track, are also missing for a variety of reasons. Note, however, that the amount of missing data is relatively small and is not expected to affect the conclusions obtained.

Courses Assessed for C2.3 (Design Experiments)	Academic Year				
	Year 1 RC-6 2012-13	**Year 2 RC-6 2013-14**	**Year 3 RC-6 2014-15**	**Year 4 RC-6 2015-16**	**Year 5 RC-6 2016-17**
ENCH 225: Lab reports (Fall)	**Not offered**	**0**	**0**	**0**	**0**
ENCH 225: Lab reports (Spring)	**0**	**0**	**0**	**0**	**0**
ENCH 425: Specific HW(s)	**15**	**28**	**8**	**13**	**18**
ENCH 437L: LR (Unsteady-state lab)	**21**	**24**	**10**	**5**	**8**
ENCH 485L: LR (Design Own Exp)	**0**	**ND**	**ND**	**0**	**0**
Overall Average % for C2.3 (Goal ≤ 10%)	**10**	**17**	**5**	**6**	**8**

Courses Assessed for C2.4 (Analyze Data)	Year 1 RC-6 2012-13	Year 2 RC-6 2013-14	Year 3 RC-6 2014-15	Year 4 RC-6 2015-16	Year 5 RC-6 2016-17
ENCH 225: Final Ex Prob. (Fall)	**Not offered**	**27**	**14**	**15**	**0**
ENCH 225: Final Ex Prob. (Spring)	**29**	**24**	**14**	**16**	**6**
ENCH 437L: LR rubric (Unsteady state heat transfer lab.)	**21**	**18**	**5**	**12**	**13**
ENCH 440: HW/E	**5**	**9**	**13**	**7**	**4**
ENCH 485L: LR Results	**0**	**ND**	**ND**	**13**	**13**
Overall Average % for C2.4 (Goal ≤ 10%)	**16**	**17**	**11**	**12**	**7**

Table 4.A.4-5: Results from Yearly Assessment for CBEE Student Outcomes C2.3 and C2.4. Data reported as the percent of students who did not pass the direct assessment item but who passed the course for 5 consecutive years in the current review cycle. To determine the averages shown, both sections of ENCH 225 are combined and counted as a single course, and ENCH 437L and 485L are also combined and counted as a single course. A deficiency in achieving an overall average yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded) and ND denotes no data are available.

Table 4.A.4-5 demonstrates that the course modifications implemented during the time period under consideration were successful in changing the overall assessment of the outcomes shown from an unsatisfactory state to a satisfactory state. In particular, several modifications related to these outcomes were introduced into two different sophomore-level and junior-level courses (*i.e.*, ENCH 225 and ENCH 425) as described later in this section. As shown in the table, the major effect of these changes was a significant improvement in the outcome assessments for the senior-level course ENCH 437L where a summative (i.e., end of program) assessment is obtained, while the other course in the analysis that provide formative (i.e., in progress)

assessments showed smaller improvements. Evidently, the benefits of the changes made in the lower-level courses accumulated and were most apparent in the senior-level ENCH 437L course. The year-to-year trends in the assessments for ENCH 437L are presented in Figure 4.A-1 where the trends just mentioned can be observed with more clarity.

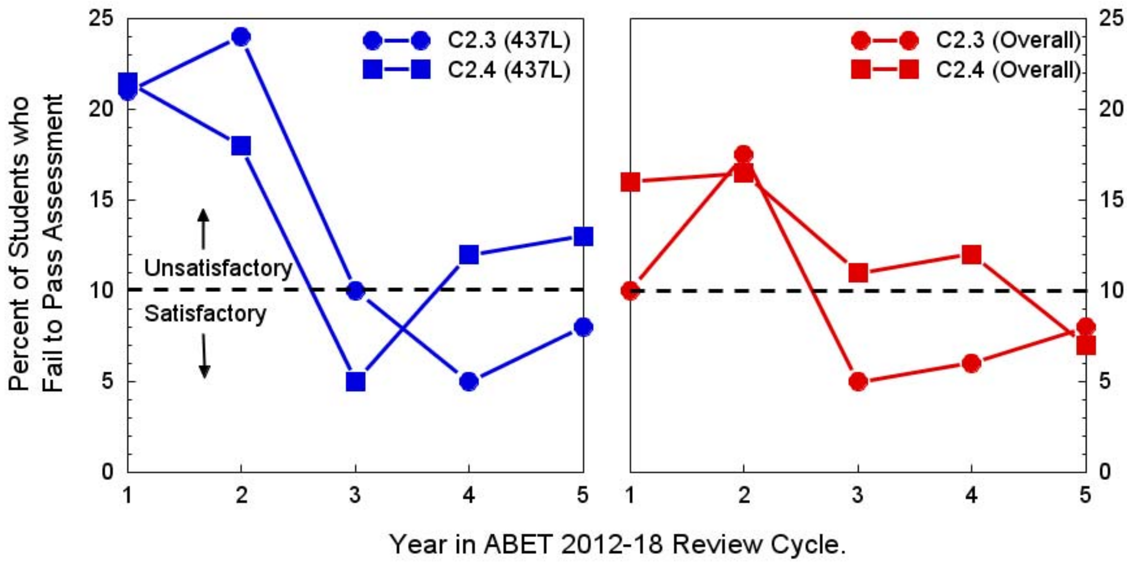


Figure 4.A-1: Visualization of Yearly Trends for CBEE Outcomes C2.3 (Design and Conduct Experiments) and C2.4 (Analyze Data) for 5 Consecutive Years in ABET 2012-18 Review Cycle. Left figure shows summative (i.e., end of program) assessment results obtained in the senior-level course ENCH 437L. Right figure shows the overall (i.e., average for all courses) assessment results.

Details of major specific program changes that contributed to the assessment improvements for CBEE Outcomes C2.3 and C2.4 are shown immediately below in the chronological order of their implementation (see also Sections C2.3 and C2.4 in Table 4.B-1 which is located in Section 4.B.3 presented below).

- **C2.4: Analyze Data (ENCH 225):** In the 2013 Spring semester a new exercise was developed in ENCH 225 in which students were given sample data sets and/or word problems. The students were then required to report statistical conclusions that could be drawn from the data and/or write computer programs to analyze and plot the data. Also, problem-based learning sessions related to analyzing data were increased.

- **C2.3: Design and Conduct Experiments (ENCH 425):** In order to expand the range of courses involving the design and conducting of experiments, two experiments were included in the ENCH 425 course material starting in the Fall 2014 semester. This change served to provide students with significant experience related to conducting experiments and analyzing data in their junior year, which was previously missing. Students conducted the experiments related to the unsteady state draining of a tank and the steady state flow through pipes, analyzed the data obtained and submitted written reports summarizing their conclusions.

- **C2.3: Design and Conduct Experiments (ENCH 225)**: In order to provide additional experience related to experimentation in the early stages of the curriculum, Laboratory 5 in ENCH 225 was revised to be a true laboratory exercise, as opposed to being a qualitative "fun lab" as it was previously. These revisions, which were implemented in the 2016 Spring semester, involved having each student group pick a chemical process and examine the steps in the process. Then the students picked a particular step in the process and designed an experiment to investigate some aspect of the chosen step. Finally, the students performed their experiment and the associated data analysis on their own. The crucial part of the revision is that students were forced to think critically about the experiment they were doing.

The next example of a detailed outcome assessment analysis considered here is for Student Outcome C1.2 (Demonstrate proficiency in chemical engineering principles). According to Table 4.A.1-1 the courses assessed for Student Outcome C1.2 are ENCH 215 (Chemical Engineering Analysis), ENCH 300 (Thermodynamics), ENCH 425 (Transport Processes I: Fluids), ENCH 427 (Transport Processes II: Heat and Mass Transfer), and ENCH 440 (Chemical Engineering Kinetics). Table 4.A.4-6 summarizes details of the courses and assessment methods for this outcome and indicates the years in which the courses are taken.

Student Outcome	Sophomore Year Course	Junior Year Courses			
	215	**300**	**425**	**427**	**440**
C1.2 Demonstrate Proficiency in Chemical Engineering Principles	E/F	E/F	E/F	E/F	E

Table 4.A.4-6: Courses where Assessment Occurs and Assessment Methods Used for CBEE Student Outcome C1.2. E denotes midterm examination and F denotes final examination.

Table 4.A.4-7 shows results from the yearly assessment for CBEE Student Outcome C1.2 for the time period 2012-2017. As discussed earlier, an assessment is considered to be attained satisfactorily if the percent of students who did not pass the direct assessment item, but who passed the course, was 10% or less. As shown in the table, the assessments for the individual courses frequently were above the 10% level, although the overall average assessment was typically 10% or less and therefore was satisfactory over the time period being considered.

Courses Assessed for C1.2 (Demonstrate Proficiency in Chemical Engineering Principles)	**Academic Year**				
	Year 1 RC-6 2012-13	**Year 2 RC-6 2013-14**	**Year 3 RC-6 2014-15**	**Year 4 RC-6 2015-16**	**Year 5 RC-6 2016-17**
ENCH 215: Exam/Final Problems	**9**	**8**	**5**	**ND**	**16**
ENCH 300: Exam/Final Problems	**25**	**11**	**11**	**9**	**5**
ENCH 425: Exam/Final Problems	**9**	**22**	**10**	**14**	**4**
ENCH 427: Exam/Final Problems	**3**	**5**	**5**	**19**	**15**
ENCH 440: Exam Problems	**0**	**0**	**0**	**7**	**6**
Overall Average % for C1.2 (Goal ≤ 10%)	**9**	**9**	**6**	**12**	**9**

Table 4.A.4-7: Results from Yearly Assessment for CBEE Student Outcome C1.2 Data reported as the percent of students who did not pass the direct assessment item but who passed the course for 5 consecutive years in the current review cycle. A deficiency in achieving an

overall yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded) and ND denotes no data are available.

The year-to-year trends in the assessments for the courses under consideration for Student Outcome C1.2 can be visualized with more clarity in Figure 4.A-2. As just mentioned, the assessment results for the individual courses shown in the left figure frequently were above the 10% level indicating unsatisfactory assessments. However, there are no obvious trends in the results displayed in that figure, while at the same time the average assessment results shown in the right figure demonstrate a roughly constant satisfactory assessment level near 10% in value. This indicates that the variations in individual course assessments shown in the left figure largely compensate for each other, and are therefore to some extent due to random influences. However, some sources of systematic variation are also evident, such as the increased assessment variability that typically coincides with a course instructor change (see the dashed line segments between data points in the figure).

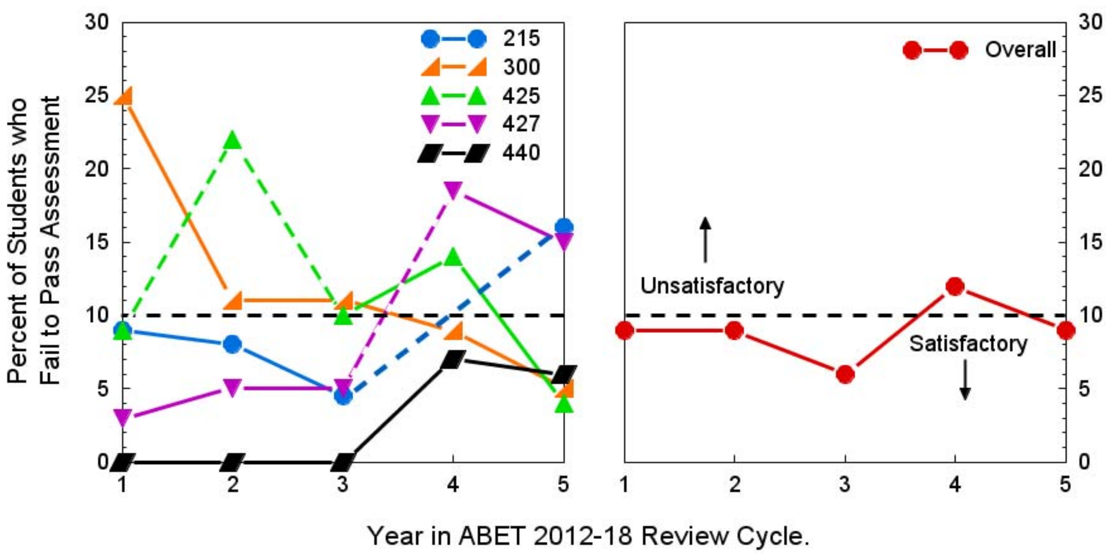


Figure 4.A-2: Visualization of Yearly Trends for CBEE Student Outcome C1.2 (Demonstrate Proficiency in Chemical Engineering Principles) for Five Courses and for 5 Consecutive Years in the ABET 2012-18 Review Cycle. Left figure shows assessment results for five individual courses. Right figure shows results for the overall (i.e., average for all courses) assessment. A dashed line segment between data points denotes that there was a change in instructor for the course.

Consider next the detailed assessment results for CBEE Student Outcome C1.3 (Design processes). It can be seen in Table 4.A.4-3 (shown previously) that the overall average assessment was generally satisfactory for the entire review cycle. Tables 4.A.4-8 and 4.A.4-9 describe the courses involved in this outcome, the assessment methods used, and values obtained for the assessments. The year-to-year trends in the assessments for the courses under consideration here can be visualized with more clarity in Figure 4.A.4-3. It can be seen that, similar to the previous case of Student Outcome C1.2, the variations in assessments for the individual courses compensate each other to produce a satisfactory overall average assessment at a roughly constant level near 10% during the entire review cycle. Figure 4.A-3 also clearly shows the progression in learning outcomes from the formative stage to the summative stage. In particular, the junior-level courses ENCH 300 and ENCH 440 exhibit significant variations in assessment results that are frequently greater than 10% in value, while the senior-level ENCH 445 course exhibits results that are less variable and more nearly satisfactory, and finally the two design-intensive senior-level courses as well as the overall average result for all courses demonstrate satisfactory assessments. Note that there were minimal changes in instructors for the set of courses under consideration here, which reduced the variability of the data so that the underlying trends become more obvious.

Student Outcome	Junior Year Courses		Senior Year Courses		
	300	440	444	445	446
C1.3 Design Processes	E	E	E/HW	HW	P

Table 4.A.4-8: Courses where Assessment Occurs and Assessment Methods Used for CBEE Student Outcome C1.3. E denotes midterm examination, P denotes a project, and HW denotes homework.

Courses Assessed for C1.3 (Design Processes)	Academic Year				
	Year 1 RC-6 2012-13	Year 2 RC-6 2013-14	Year 3 RC-6 2014-15	Year 4 RC-6 2015-16	Year 5 RC-6 2016-17
ENCH 300: Exam	**20**	**11**	**23**	**32**	**14**
ENCH 440: Exam	**5**	**14**	**3**	**3**	**7**
ENCH 444: E/HW	**0**	**0**	**0**	**ND**	**5**
ENCH 445: HW	**17**	**13**	**15**	**12**	**15**
ENCH 446: Project	**5**	**7**	**0**	**0**	**0**
Overall Average % for C1.3 (Goal ≤ 10%)	**10**	**10**	**8**	**12**	**8**

Table 4.A.4-9: Results from Yearly Assessment for CBEE Student Outcome C1.3 Data reported as the percent of students who did not pass the direct assessment item but who passed the course for 5 consecutive years in the current review cycle. A deficiency in achieving an overall yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded) and ND denotes no data are available.

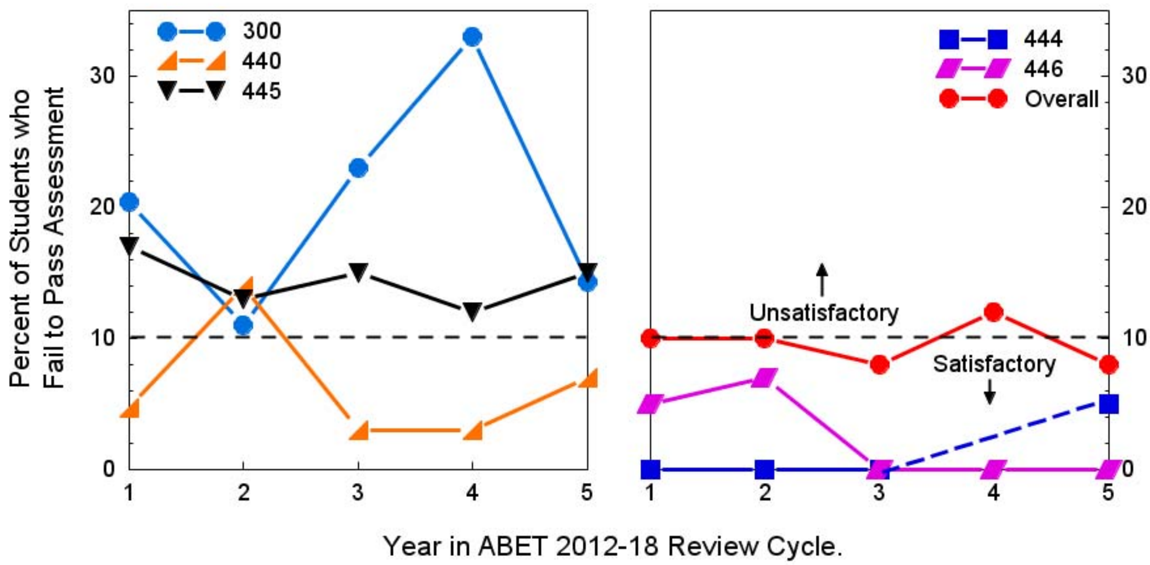


Figure 4.A-3: Visualization of Yearly Trends for CBEE Student Outcome C1.3 (Design Processes) for Five Courses and for Five Consecutive Years in the ABET 2012-18 Review Cycle. Left figure shows assessment results for three courses, including two junior level courses, where design is a minor component of the course. Right figure shows results for the summative (i.e., end of program) assessment obtained in ENCH 444 and 446 where design is a major component of the course, and results for the overall average assessment for all the courses under consideration. A dashed line segment between data points denotes that there was a change in instructor for the course.

Consider finally the detailed assessment results for CBEE Student Outcome C1.1 (Foundation in Math/Science). Tables 4.A.4-10 and 4.A.4-11 describe the courses involved in this outcome, the assessment methods used, and values obtained for the assessments. The year-to-year trends in the assessments for the courses under consideration can be visualized with more clarity in Figure 4.A-4. As shown, the results for the sophomore- and junior-level courses exhibit significant variations in assessment results that frequently were well above the 10% level that is considered satisfactory. This is especially apparent for ENCH 442 where 57% of the student failed to achieve a satisfactory level of assessment in the 2015-16 academic year. However, this same cohort of students achieved a nearly satisfactory summative (i.e., end of program) outcome assessment in the senior-level ENCH 445 course in the following 2016-17 academic year. This suggests that the unsatisfactory overall assessment received in the 2015-16 academic year cannot be used to justify a program-wide course improvement effort since it is largely due to the assessment in a single course where an instructor change occurred and it is not supported by other evidence.

Student Outcome	Sophomore and Junior Year Courses				Senior Year Course
	215	425	440	442	445
C1.1 Foundation in Mathematics and Science	F	E/F	E	E	E/HW

Table 4.A.4-10: Courses where Assessment Occurs and Assessment Methods Used for CBEE Student Outcome C1.1. E denotes midterm examination, F denotes final examination, and HW denotes homework.

Courses Assessed for C1.1 (Foundation Math/Science)	Academic Year				
	Year 1 RC-6 2012-13	Year 2 RC-6 2013-14	Year 3 RC-6 2014-15	Year 4 RC-6 2015-16	Year 5 RC-6 2016-17
ENCH 215: Final	**2**	**3**	**4**	**ND**	**9**
ENCH 425: Exam/Final	**9**	**22**	**4**	**14**	**4**
ENCH 440: Exam	**0**	**0**	**3**	**16**	**4**
ENCH 442: Exam	**20**	**2**	**4**	**57**	**21**
ENCH 445: Exam/HW	**17**	**16**	**8**	**5**	**11**
Overall Average % for C1.1 (Goal ≤ 10%)	**10**	**9**	**5**	**23**	**10**

Table 4.A.4-11: Results from Yearly Assessment for CBEE Student Outcome C1.1 Data reported as the percent of students who did not pass the direct assessment item but who passed the course during the current review cycle. A deficiency in achieving an overall yearly outcome is denoted by an entry in red numerals. RC-6 denotes the current (2012-2018) ABET review cycle (the sixth review cycle since the CBEE Department was founded) and ND denotes no data are available.

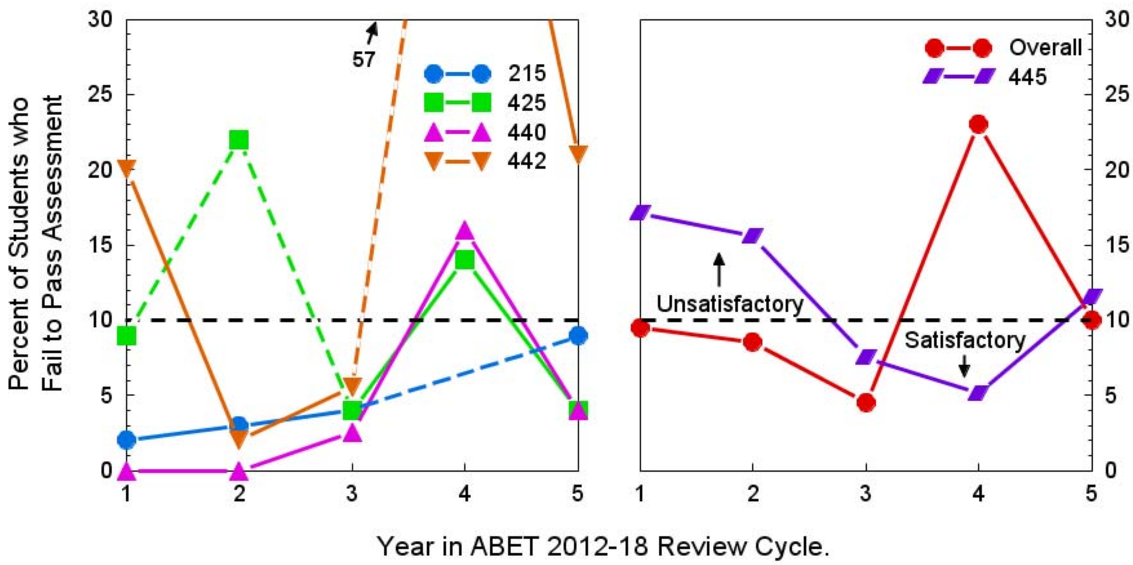


Figure 4.A-4: Visualization of Yearly Trends for CBEE Student Outcome C1.1 (Foundation Math/Science) for Five Courses and for Five Consecutive Years in the ABET 2012-18 Review Cycle. Left figure shows formative (i.e., in progress) assessment results for one sophomore and two junior level courses. Right figure shows results for the summative (i.e., end of program) assessment obtained in ENCH 445 and results for the overall average assessment for all the courses under consideration. A dashed line segment between data points denotes that there was a change in instructor for the course.

4.A.4.c Summary of Selected Results from Indirect Assessments of Student Outcomes

The indirect methods used by the CBEE Department to assess the attainment of student outcomes by graduating seniors consist of yearly exit interviews, focus group discussions, and exit surveys. These methods address topics that vary substantially from year-to-year and typically provide subjective and anecdotal information. Indirect assessment results have therefore been collated in the form of extracted comments and opinions, as opposed to structured tables, and are available in this form in the departmental ABET folder on Google Drive. To illustrate how indirect assessment information has led to program improvements associated with student outcomes, three examples are given below. The first two examples describe program improvements that are now fully implemented while the last example describes a course improvement effort currently in progress.

2014-15 Academic Year: Graduating seniors indicated in many of their exit interviews from the 2012-14 time period that there was no dedicated space on campus where they could meet as a team to work on group projects, such as their senior design project. Since this situation affects the ability of students to achieve CBEE Student Outcome C3.1 (Work effectively in teams), the CBEE Department decided during the 2014-15 academic year to renovate the laboratory used for ENCH 225L and convert it into dual purpose space. As a result, the room used for ENCH 225L (i.e., ENG 335) can now be used either for performing experiments when ENCH 225L laboratory sessions are being conducted, or as a meeting space for student groups at other times.

2015-16 Academic Year: A common concern expressed in the exit interviews for the graduating seniors in the 2012-15 time period was that students did not have good access to the computer laboratories on campus. This made it difficult for students to use software that was needed in their courses, such as Aspen. Consequently, the CBEE Department negotiated with the UMBC Division of Information Technology (DoIT) in order to grant swipe card access for students to the computer laboratory in ENG 336. As a result, starting from the 2015-16 academic year students now have essentially continuous access to a UMBC computer laboratory and all the software needed in their courses including Aspen. This significantly enhances the ability of students to achieve CBEE Student Outcome C1.4 (Use modern tools).

2016-17 Academic Year: In exit interviews conducted over the last several years, including for the 2016-17 academic year, a common concern has been that the second semester of the two-semester physical chemistry course sequence taught by the Chemistry Department at UMBC (i.e., CHEM 302) is not relevant to the chemical engineering curriculum. Since this situation affects CBEE Student Outcome C1.1 (Foundation in Math/Science), the department investigated the content in CHEM 302 with the aim of improving it. It was determined that CHEM 302 focused nearly exclusively on the topics of quantum mechanics and spectroscopy and did not include topics typically included in a second-semester physical chemistry course of interest to chemical engineering students. One central missing topic was the use of statistical mechanics to quantitatively connect the behavior of bulk physical matter to the molecular-scale behavior described by quantum mechanics. To obtain further background information, the CBEE Department also reviewed the role of physical chemistry courses at other leading chemical engineering departments and determined that there was a large variation in this role. For example, at one extreme was the case of Stanford where the physical chemistry courses are required and are sufficiently integrated into the chemical engineering curriculum so that these courses, even though they are taught by the Chemistry Department, are counted in the "engineering topics" category in the ABET course classification instead of the "math/science" category. At the other extreme are the cases of Georgia Tech and North Carolina State University where the requirement to take physical chemistry courses has been eliminated. By using these cases and others as example solutions, the CBEE Department will finalize a decision on how to incorporate CHEM 302 in the curriculum during the 2017-18 academic year.

4.A.5 Maintenance and Documentation of Results

All electronic documents, Excel spreadsheets, and similar items related to assessing student outcomes as described in this section are stored in a subfolder located in the departmental main ABET folder on Goggle Drive.

4.B. Continuous Improvement

4.B.1 Information Used for Program Improvement

As a result of the assessment processes described above, significant amounts of data are gathered to assist faculty in program evaluation and decision-making regarding program improvements. These types of data include both direct and indirect measures of student learning as well as feedback from a variety of constituencies, such as results from the survey of alumni or comments from the CBEE Advisory Board. Upon yearly evaluation of the data trends, the CBEE Undergraduate Committee first assesses the need for overall program improvements and then brings the discussion to the full faculty for consideration as shown in the timeline below. Once specific program improvements have been determined, individual instructors are responsible for enacting the changes in their courses. Specific examples of program improvements since the last ABET review are detailed in Table 4.B-1 shown below.

4.B.2. Yearly Timeline for Continuous Improvement

1. Assessment data are collected throughout a particular academic year (September-May)
2. Data from assessments are collated and analyzed by the ABET Coordinator (June/July)
3. The analyzed assessment data are discussed by the Undergraduate Committee (UGC). The UGC evaluates the effectiveness of prior program changes, identifies areas for program improvement and develops recommended changes in the program or individual courses. The UGC also considers whether or not corrective course improvements based on assessments are already being considered by instructors in individual courses, or whether course improvements need to be coordinated at the program level (mid-August)
4. Recommendations for changes are made to the full departmental faculty. The departmental faculty discusses these recommendations and provides input (fall semester)
5. CBEE Advisory Board is updated with regard to proposed program changes and provides input. (May/June)
6. The Department Chair, the Undergraduate Program Director, the ABET Coordinator, and the course instructors for the courses involved in a particular issue (if any) decide on a solution for the issue being considered. This solution is based to the extent possible on input from the various departmental constituencies as described above
7. Changes are implemented throughout the succeeding academic year (September-May)
8. Steps 1 – 7 are repeated for the next academic year.

4.B.3 Actions to Improve the Program

There are two distinct routes for identifying actions that will improve the program. In the first case, an individual instructor may choose to modify his/her course content based on experience, assessments of student learning, class performance on specific assignments, or data from the Direct Assessment Document for a course. Modifications of this type are documented to the extent possible, including through the use of an optional Closing-the-Loop Document which instructors complete and upload to the appropriate subfolder in the departmental ABET folder on Google drive. Similarly, the departmental undergraduate advisors may alter advising procedures upon consensus of the CBEE Undergraduate Committee. The second route used to improve the program occurs when the CBEE Department obtains consistent outcome assessments over multiple years, or consistent feedback from multiple constituencies, indicating a specific curriculum-wide area for improvement. In this situation, specific actions are taken at the departmental level often resulting in changes to multiple courses or processes.

Sections 4.A.4.b and 4.A.4.c presented earlier describe the processes used for obtaining and evaluating direct and indirect outcome assessments. For completeness when describing those processes, those sections also described several course and program improvements that were associated with outcome assessments. In the remainder of this section a chronological listing is given of the major improvements to the program since the last ABET review (see Table 4B-1).

Table 4.B-1: Improvements made to the CBEE Program since the last ABET visit demonstrating our commitment and success in continual improvement of our educational process (in chronological order).

C1.1 Foundation in Mathematics and Science				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 215 Leach	Fall 2017 (anticipated)	Increased discussion including problem based learning sessions were groups solve foundational problems while instructor and/or TFs provide guidance.	9% of the class fell below the minimum standard during Fall 2016 semester	To be determined

C1.2 Proficiency in Chemical Engineering Principles				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 300 Castellanos	Fall 2013	Introduced metacognition in the Thermodynamics class, students write reflection paragraphs (8-12) throughout the semester	Historically students have struggled with this course, most other universities have thermodynamics divided in 2 semesters, and we have one. The attempt is try help students think more deeply about what they are doing.	Students are asked to rate their experience in the class, students sense a deeper understanding, additionally there is an increment in grades (still need to look into statistical significance)
ENCH 412 Blaney	Spring 2013	Added material on advanced processes in environmental engineering	To increase student proficiency in not only conventional, but also advanced water treatment processes	Students are better prepared for future positions in graduate school and consulting
ENCH437L Leach and Castellanos	Fall 2014	Modified course delivery to be co-taught	To increase practice in core competency areas, and provide more opportunity to guide the development of critical thinking skills and writing.	Provides time for feedback on writing to accommodate increased enrollments.
ENCH440 Marten	Spring 2015	Implemented quizzes on each chapter in the text BEFORE we begin discussion of this material in class.	This forces students to study, and presumably learn, material from the text before class. This allows much deeper discussion during class and extended periods for interactive problem solving during class.	Students were initially resistant, but in the end appreciated this approach as it provided a better understanding of the material.
ENCH 445 Frey	Fall 2015	Developed a course "WebBook" to complement the printed textbook used in the course.	The printed textbook used in the course omitted several important concepts that were needed to properly teach the course material (such as the "Description Rule")	Students now have a better fundamental understanding of the basic principles that underlie the course material
ENCH440 Marten	Spring 2016	Implemented extensive use of conceptual questions from CU LearnChemE web site.	This helps students think more deeply about the relationship between relevant phenomena without being distracted by the finding equations or the quantitative nature of a problem.	Students are developing a much deeper and more thorough understanding of the underlying principals and relationships between them relevant to kinetics.

ENCH 225L Szeto/ Castellanos	Spring 2016	Added MATLAB-based open-ended homework problems	This exposes students to core chemical engineering topics (heat and mass transfer, kinetics) earlier, providing a transition to junior year topics.	Students became more resourceful at information gathering and independent thinking, reaching out to team and peers, and working on complex problems where they may not see a clear solution.
ENCH 425 Raikar	Fall 2016	Added in class concept questions via use of clickers	Students think more about the concepts taught in class.	Student interaction improved and so did their understanding of core concepts
ENCH 442 Raikar	Spring 2017	In class concept questions through the use of clickers were added	The concepts in the class were taught more effectively to the students.	There was an improvement in both student interaction and understanding of core concepts
ENCH 215 Leach	Fall 2017 (anticipated)	Increased discussion including problem based learning sessions were groups solve applied material and energy balance problems while instructor and/or TFs provide guidance.	16% of the class fell below the minimum standard during Fall 2016 semester.	To be determined
C1.3: Design Processes				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 412 Blaney	Spring 2013	Class tour and question/answer at Ashburton Water Filtration Plant (Baltimore, MD)	Enable students to get exposure to full-scale treatment operation and engage with practitioners in the field	Students get a better appreciation of practical challenges in the design and operation water quality scientist
ENCH 474 Hennigan	Fall 2014	HW Problem sets required design of air pollution control systems	Reinforces technical knowledge; connects different courses across the engineering curricula	Students applied these principles in Senior Design I & II
ENCH 414 Ghosh	Fall 2014	Field trip to Back River wastewater treatment plant in Baltimore	Enable students to get exposure to full-scale treatment operation and engage with practitioners in the field	Students get a better appreciation of practical challenges in the design and operation
ENCH 310 Blaney	Fall 2015	Instituted team project	To increase team and peer-to-peer based learning, and to encourage students to design for open-ended problems; increased use of computers in curriculum	Student teams designed their own questions for resource recovery efforts and used MINEQL+ to design process

C1.4: Use Modern Tools				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH485L Leach	Spring 2012	Moved course to dedicated teaching space (Eng 334B) and purchased new laboratory equipment.	Previously, the course was taught in research space, which compromised student safety and teaching effectiveness.	Provides students with dedicated space and new equipment.
ENCH485L Leach	Spring 2013	Added experiment on process stresses (effect of shear, temperature and air/water interface on protein stability/structure).	To increase students understanding of the development and manufacturing of protein-based drugs and products.	Provides opportunity for students to learn modern tools and concepts related to the biotech industry.
ENCH437L Leach and Castellanos	Fall 2014	Added new "virtual" lab (absorption simulation). Report assignment broken into 3 stages to provide stage-by-stage feedback on first report.	To increase competency in simulation experiments and software and to provide more opportunity to guide the writing process.	Provides more opportunities for students to better learn the writing process and simulation tools without purchasing new equipment.
ENCH 445 Frey	Fall 2015	Introduced students to COCO software, which is free software for chemical process simulation that employs the "CAPE-Open" (Computer-Aided Process-Engineering Open Source) "plug-and-play" software interface standard Also developed three YouTube video tutorials and a YouTube channel to help students learn to use COCO	COCO complements the use of ASPEN for chemical process simulation problems	Students gained better skills in process simulation by using two different and complementary software systems for chemical process simulation.
ENCH 310 Blaney	Fall 2015	Instituted MINEQL+ chemical equilibrium modeling software module	To increase ability of students to quickly solve complex environmental chemistry problems	Students introduced to modern tools that allow quick assessment of environmental chemistry
ENCH 442 Raikar	Spring 2016	Introduced students to Simulink to design and simulate control loops	To expose students to other software modules in MATLAB	Students learn new tools which they use for other courses as well in their chemical engineering career.
ENCH 310 Blaney	Fall 2016	Increased the generation and sharing of Excel templates for individual course areas, as well as select homework problems, to allow students to adopt these tools for future problems and better identify their mistakes on homework problems	Written student feedback indicated a desire for more in-class co-development of Excel templates to solve course problems	Homework scores improved from 64% (2015) to 70% (2016) with marked improvement in the clarity of solutions requiring extensive data tables and plots
ENCH 215 Leach	Fall 2017 (anticipated)	Increased instruction and office hours on basic computer skill review. Increased requirement for computer programming in homework Problem Sets.	16% of the class fell below the minimum standard during Fall 2016 semester	To be determined

Student Outcome C1.5: Understand Broader Impact				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 300 Castellanos	Fall 2013	Introduced Discussion Portfolios, students will write a ‘blog post’ relating a thermodynamic concept with a real world example, Student were expected to comment on each other post. Students selected three best posts or response to be graded (“twice a semester)	Student have complained about not seeing the practical sense of thermodynamics.	By the end of the semester 90% of students are able to find an application of thermodynamics in their everyday life.
ENCH485L Leach	Spring 2014	Added seminar assignment where students attended 5 seminars related to biochemical engineering.	To increase students understanding of the breadth of biochemical engineering and emerging applications of current research findings	Provides opportunity for increased knowledge of the breadth of state-of-the-art biochemical engineering research.
ENCH 210 Hennigan	Fall 2014	Assignments and in-class discussions focused on applications of Environmental Eng. from mainstream media articles	Enable students to connect the technical material with real world applications.	Students have a deeper appreciation of the role of Env. Eng. in society
ENCH 210 Hennigan	Fall 2014	Problems set is based upon current “City of Baltimore Department of Public Works Annual Water Quality Report”	To increase students awareness of Env. Eng. impacts, responsibilities, and challenges; To reinforce student resourcefulness	Students gain experience searching for technical report; Students gain perspective on career in Env. Eng. through local agency technical report
ENCH 414 Ghosh	AY2014-16	Discussion of media articles on water pollution impacts on rivers e.g. fish kills	Enable students to connect the technical material with real world problems.	Students get a closer understanding of the role of Env. Eng. in society
ENCH486 Rao	Fall 2014	Included attending Pediatric Device Innovation Conference where a “Pitch Competition” pits companies proposing ideas for a prize. In addition, talks and panels by policy makers give a broad exposure to medical device development	Students needed to experience competitive approaches to solving engineering challenges and the difficulties in bringing a product to market	Students interacted with attendees and obtained real world exposure to product design, refinement and “selling” ideas. It gave them a template to use in their own project presentations
ENCH 310 Blaney	Fall 2015	Introduction of resource recovery efforts for increased environmental sustainability	To increase students understanding of shifting paradigms in water/wastewater treatment towards resource recovery	Focused on recovery of nutrients, chromium, silver, zinc, and other valuable elements from industrial waste streams
ENCH 485L Lavik	Spring 2017	Individual presentations on how chemical engineering is involved in real world problems	Broader impacts of chemical engineering were involved in each lab, but the students were often struggling to connect the individual labs to the field and world more broadly	In progress. Early feedback from students and based on their performance was promising. Several students said following the assignment that they have rethought their career interests.

ENCH 225 Szeto/Raikar	Spring 2017	Added written milestone to final design project where teams detail Broader Impacts of their project per NSF definition	To facilitate student thought and communication on the breadth of applications and long-term goals of experiments	Gain experience thinking and writing about the implications of experiments
C2.1: Solve Open-Ended Problems				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 300 Castellanos	Fall 2013	Introduced metacognition in the Thermodynamics class, students write reflection paragraphs (8-12) throughout the semester	Historically students have struggled with this course, most other universities have thermodynamics divided in 2 semesters, and we have one. The attempt is help students think more deeply about what they are doing.	Students are asked to rate their experience in the class, students sense a deeper understanding, additionally there is an increment in grades (still need to look into statistical significance)
ENCH 300 Castellanos	Fall 2014	Turn the class into from a lecture style approach to a team based learning approach, iRATS and eRATS were introduced	Students worked on instructor design teams throughout the semester, in class, using the peer to peer learning literature	A higher number of students participate in the problem solving process, students are engaged throughout the semester, level of commitment and class participation have increased
ENCH 310 Blaney	Fall 2015	Made MINEQL+ project more open-ended	To increase students leveraging of course material/concepts to solve problems of most interest to them	Student interest in project was high; written reports were high quality and successfully incorporated material from course
ENCH 485L Lavik	Spring 2016	Addition of open ended drug delivery project with specific outcomes and design criteria	Previously, the labs taught skills in a very defined context. This project allows the students to work in a group to apply those experimental skills to a real world problem.	In progress. Presentations and reports suggest students are learning to apply the techniques to a real world problem.
ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project.	To increase immersive experience with the engineering design process from project conception to presentation of results.	Students became more adept at experimental design and analysis, increased comfort with failure and adaptation in experimental scenarios. Increase in intellectual ownership and independence.
C2.3: Design and Conduct Experiments				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH437L Leach	Fall 2013	Added new project where students design a material and energy balances experiment and build the apparatus to carry it out.	To increase competency in designing experiments and design/assembly of experimental equipment.	Provides opportunity for students to design and build experiments. Unfortunately not scalable to larger enrollments due to lack of space and infrastructure.

ENCH 425 Raikar	Fall 2014	Added two experiments to the course material	Give students more exposure to conducting experiments	Overall direct assessments have improved for C2.3 since 2014
ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project which involved converting Laboratory 5 to a more rigorous exercise.	To create an early opportunity for independent project conception, experimental design, and execution.	Students were highly detail-oriented in design and execution of their experiments.

C2.4: Analyze Data

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 440 Reed	Spring 2012	Increased time spent on data analysis problems in between homework and examinations	More emphasis on data analysis after reflecting on student weaknesses (based on HW performance)	Students did much better on examination problems related to data analysis. T
ENCH 225L Enszer	Spring 2013	Increased discussion times which included problem based learning session where lab groups worked for 50 min on an experimental design and analysis while instructors an TAs provided guidance	29% of the class fell below the minimum standard for being able to analyze data	In the Spring 2015 semester, 14% of the class fell below the minimum standard for being able to analyze data
ENCH 482 Marten	Spring 2013	Significantly increased number and type of literature articles students read and discuss in class. During in-class discussion each student is called on with an article relevant question and graded on their response.	This forces students to study article and related data, seeking outside sources for clarification and understanding. In class discussion clarifies uncertainty and help students calibrate their own out-of-class learning experience.	Consistently get comments that this is the most significant learning experience and most helpful aspect of the class.
ENCH 425 Raikar	Fall 2014	Added two experiments to the course material	Give students more exposure to analyzing data	Overall direct assessments have improved for C2.since 2014

C3.1: Work Effectively in Teams

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 444/446 Castellanos	Spring 2012	Introduced contemplative pedagogy practices	Students take Strengthsquest test and work throughout the semester in introspection exercises that makes them think how their individual behaviors affect the success or failure of their team,	Students are more aware of personal strengths and weakness and experience, self-assessment has increased
ENCH 300 Castellanos	Fall 2013	Turn the class into from a lecture style approach to a team based learning approach, iRATS and eRATS were introduced	Students worked on instructor design teams throughout the semester, in class, using the peer to peer learning literature	A higher number of students participate in the problem solving process, students are engaged throughout the semester, level of commitment and class participation have increased

ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project	Students are put in teams using CATME where they work towards a common goal of designing and optimizing a unit operation of their choice	Student's capacity for group work is strengthened early on during the program and enough time is available for conflict resolution
ENCH 225L Szeto/ Castellanos	Spring 2016	Added in-class group presentations	Students are exposed to presentations to a larger audience and feedback given by instructors and peers.	Presentation skills are improved which can benefit all future classes, career

C3.2: Fill Various Roles

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change

C3.3 Resolve Conflict

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 225L Szeto/ Castellanos	Spring 2016	Added in-class conflict resolution scenarios and discussion	Student teams encountered unexpected or difficult conflict scenarios and dynamics throughout semester.	Students were able to defuse or address theoretical and actual conflict scenarios. Teams observed and discussed diverse approaches to conflict resolution with their peers in a safe, facilitated setting**.**

C4.1: Communicate in Writing

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 225L ENCH 300 ENCH 427 ENCH 437L ENCH 442 ENCH 444 ENCH 446 ENCH 485L	Spring 2012	Included writing in the curriculum in several courses (ENCH 300, ENCH 427, ENCH 442, ENCH 444 and ENCH 446) and two core courses attained Writing Intensive Status (ENCH 225L and ENCH 437L/485L)	Technical writing was not being taught effectively by the English Department in ENGL 393 (Technical Writing). Department believed that technical writing should be taught within Chemical Engineering Department courses.	Direct assessment scores for C4.1 have steadily improved during 2012-2017 time period.
ENCH437L Leach and Castellanos	Fall 2014	Added new "virtual" lab (absorption simulation). Report assignment broken into 3 stages to provide stage-by-stage feedback on first report.	To increase competency in simulation experiments and software and to provide more opportunity to guide the writing process.	Provides more opportunities for students to better learn the writing process and simulation tools without purchasing new equipment.
ENCH 446 Castellanos	Spring 2014	Introduce Faculty participation in Capstone course	Student work with several Faculty member plus instructor throughout the semester to get different perspectives on the engineering themes of their Design Project	Students have been challenged in different ways, and are exposed to the full Faculty regardless of track.

ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project	Technical writing skills can be enhanced further through various milestones of the design project	Additional technical writing opportunities will increase student comfort and skills in this area

C4.2: Communicate Orally

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 412 Blaney	Spring 2012	Instituted team-based project on advanced treatment of emerging contaminants	To increase student understanding of emerging concerns in environmental engineering	Provided students with opportunity to leverage material from course to describe advanced processes
ENCH482 Marten	Spring 2013	Significantly increased number and type of literature articles students read and discuss in class. During in-class discussion each student is called on with an article relevant question and graded on their response.	This forces students to study article and related data, seeking outside sources for clarification and understanding. In class discussion clarifies uncertainty and help students calibrate their own out-of-class learning experience.	Consistently get comments that this is the most significant learning experience and most helpful aspect of the class.
ENCH 446 Castellanos	Spring 2014	Introduce Faculty participation in Capstone course	Student work with several Faculty member plus instructor throughout the semester to get different perspectives on the engineering themes of their Design Project	Students have been challenged in different ways, and are exposed to the full Faculty regardless of track.
ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project with final oral presentation.	Previous course design focused solely on written lab reports. This design diversified exposure to different communication scenarios.	Students practiced oral presentation design and execution.
ENCH 225L Szeto/Raikar	Spring 2017 (in progress)	Added scientific poster presentation	To expose students to different presentation formats	o be determined

C5.1 Define Problems

Course and Instructor	Semester of Implementation	Curricular or Program Change	Rationale for Change	Impact of Change
ENCH 225L Szeto/ Castellanos	Spring 2016	Added semester-long team design project	Stimulate independent and creative thinking	To be determined over few more years of implementation
ENCH 225L Szeto/ Castellanos	Spring 2016	Added open-ended MATLAB homework problems	Stimulate independent and creative thinking, build confidence in complex problem solving with unfamiliar concepts.	Students became more adept at parsing large complex problems into small increments for learning, solution, and troubleshooting.
ENCH 310 Blaney	Fall 2016	Changed the project prompt to be more open-ended, and allowed the students to identify (and define) any project that utilized the principles taught in the course	Student teams completed course projects, but many chose problem ideas that were mentioned in the project prompt	Project scores improved from 84.9% (2015) to 90.4% (2016), and the diversity of project subjects improved

C5.2: Locate Information				
Course and Instructor	**Semester of Implementation**	**Curricular or Program Change**	**Rationale for Change**	**Impact of Change**
ENCH 412 Blaney	Spring 2013	Physicochemical information for chemicals of concern not provided in homework questions or textbook	To increase students ability to locate fundamental properties/parameters using a variety of available resources	Students became familiar with CRC handbook, EPISuite (EPA), NIST WebBook, and ChemAxon
ENCH 412 Blaney	Spring 2013	Physicochemical information for chemicals of concern not provided in homework questions or textbook	To increase students ability to locate fundamental properties/parameters using a variety of available resources	Students became familiar with CRC handbook, EPISuite (EPA), NIST WebBook, and ChemAxon
ENCH482 Marten	Spring 2013	Significantly increased number and type of literature articles students read and discuss in class. During in-class discussion each student is called on with an article relevant question and graded on their response.	This forces students to study article and related data, seeking outside sources for clarification and understanding. In class discussion clarifies uncertainty and help students calibrate their own out-of-class learning experience.	Consistently get comments that this is the most significant learning experience and most helpful aspect of the class.
ENCH 474 Hennigan	Fall 2013	Regulatory emission standards for sources or industrial sectors not provided in HW sets	To increase students ability to locate and interpret technical materials	Students gain experience with EPA tools
ENCH 225L Szeto/ Castellanos	Spring 2016	Introduced more open-ended problems in homework and final design project	Require students to work on acquiring, learning, and applying knowledge not directly given in lectures for problem-solving and data analysis. Increase comfort and experience in scenarios where pre-existing knowledge is limited.	Students gain experience mining online scientific literature (Pubmed, Google Scholar), other web resources, and peers
Other Experiences				
ENCH 412 Blaney **Other Professional Skills**	Fall 2013	Class tour and question/answer at Ashburton Water Filtration Plant (Baltimore, MD)	Enable students to get exposure to full-scale treatment operation and engage with practitioners in the field	Students get a better appreciation of practical challenges in the design and operation water quality scientist
ENCH 414 Ghosh **Other Professional Skills**	Fall 2015	Field trip to Back River wastewater treatment plant in Baltimore	Enable students to get exposure to full-scale treatment operation and engage with practitioners in the field	Students get a better appreciation of practical challenges in the design and operation
Multiple Courses	Fall 2015	Undergraduates were given increased opportunities to function as Teaching Fellows to help with course grading and the holding of office hours.	Growing enrollments made it difficult to assist teaching using only graduate-level teaching assistants. Undergraduates were also provided opportunities to help teach courses	Undergraduates were able to learn course material better b helping to teach courses.
ENCH 225L Szeto/Raikar **Other Professional Skills**	Fall 2017 (anticipated)	Introduce entrepreneurship components via the Alex Brown Center	Allow students to get entrepreneurship experience as well as earn entrepreneurship credits to count towards their ENTR minor	To be implemented
Improvements in Advising and Student Support				

	Spring 2015	CBEE repeat policy has been changed to match that of other COEIT engineering departments so that third attempts are not allowed except under exceptional circumstances.	To ensure that policies are appropriately and consistently applied.	Students who are not able to progress adequately in the program are advised on other academic options at UMBC
	Fall 2015	Added to the number of UG advisors from all academic ranks	UG students required more detailed advising to stay on track in program	Additional advisors allows more detailed advising
	Spring 2016	PeopleSoft recoded to determine if CBEE students have passed the proper prerequisites	University wide effort Eliminates the need for faculty to individually check student's right to be in a class	Allows for more time for advisors to meet with students. System is still being debugged and is not yet fully operational.
Major Infrastructure Improvement				
	Fall 2015	Renovated laboratory space and purchased new furniture for a student learning centered room (ENG 335).	In response to exit interviews of students who identified the lack of meeting and study space where they could work on projects, receive tutoring, etc	Students reported that it was easier to meet for group projects and an increase in the use of student study groups
	Fall 2016	Students gained swipe card access to computer laboratory in ENG 336	In response to exit interviews of students who indicated they had difficulty accessing computer laboratories to use Aspen and other software	Students reported much easier access to computer laboratories.
Major Program Changes				
	AY 2011-12	Initiation of Environmental Engineering and Sustainability Track	In response to significant student interest, to participate in a major university initiative and in response to the merger of departments	To be determined; undergraduate enrollment is expected to increase.
Changes in Assessment Strategies				
	Fall 2014	Remove ENES 101 from CBEE assessment responsibilities	ENES 101 became a college wide course without sections specific for CBEE UGs. CBEE students could not be separately assessed any longer.	To be determined.
	Fall 2015	Retain Student Outcome C1.4 (Use of Modern Tools)	In response to DA data that indicates use of modern tools such as ASPEN, Matlab needs to be emphasized	Continual focus on developing this skill for CBEE UGs

4.C. Additional Information

Copies of all assessment instruments and materials will be available for review at the time of the visit. To the extent possible, minutes from meetings where assessment results were evaluated and where recommendations for actions were made will be included. Tables 4.C-1 through 4.C-4 below give the rubrics used for direct assessment as described in Section 4.B. Examples of Close the Loop Documents and Direct Assessment Documents are also provided below.

4.C.1 Rubrics for Student Outcomes.

Criterion	Exemplary (3 points)	Satisfactory (2 points)	Developing (1 point)	Novice (0 points)
1. Attends team meetings (C3.1)	Rarely absent from team meetings or work session.	Is absent occasionally, but does not inconvenience group.	Is absent frequently, sometimes to the detriment of group actions	Is absent from team meetings or work sessions >50% of the time.
2. Prepares for team meetings (C3.1)	Well prepared for group meetings with clearly formulated ideas	Prepares assigned tasks, but ideas are incomplete or not well formulated	Prepares somewhat for group meetings; ideas are not well thought out or not well formulated	Routinely fails to prepare for meetings; assigned tasks frequently not completed; rarely contributes new ideas.
3. Works collaboratively with other team members (C3.1)	Fully cooperates with others; shares information and provides assistance to others ; shares credit for success; courteous of others	Rarely works as a loner; shares information willingly; occasionally inconsiderate; acknowledges the contributions of others	Occasionally works as a loner; not very willing to share information; not always considerate or courteous to other team members; occasionally acknowledges the contributions of others	Does work on his/her own; does not value teamwork; hides in background or participates only when strongly encouraged; discourteous of other team members; claims or attempts to claim an inappropriate amount of personal credit
4. Brings appropriate knowledge and information to the team (C3.1)	Technically skilled within discipline with good extra disciplinary knowledge; makes appropriate contributions to extra-disciplinary discussions	Technically competent within discipline, with some extra discipline knowledge; can contribute to extra-disciplinary discussions	Technically competent within discipline, but rarely has technical knowledge or other disciplines; gets lost in extra-disciplinary discussions	Has limited knowledge both within and outside of discipline; limited technical contributions
5. Assumes appropriate responsibility within the team in a variety of roles (C3.2)	Demonstrates the ability to assume a designated responsibility in a variety of roles within the group	Assumes designated responsibility that varies with role, but with limited enthusiasm and follow-through	Resists designated responsibilities, or insists on specific responsibility; may unilaterally assume a responsibility not assigned	Does not willing assume assigned responsibility, and/or does not follow through on assigned responsibility
6. Displays appropriate intra-team social and conflict resolution skills (C3.3)	Values alternative perspectives; usually remains non-judgmental when disagreeing; seeks conflict resolution	Occasionally inappropriately judgmental during disagreements; rarely seeks conflict resolution; tolerates alternative perspectives	Regularly inappropriately judgmental during disagreements; may initiate intra-team conflict; not interested in alternative perspectives	Frequently expresses inappropriate criticism of other group members; regular source of intra-team discord; exhibits disdain for alternative perspectives; does not work to resolve conflict

Table 4.C-1: Rubric for CBEE Student Outcome C3.1: Work Effectively in Teams, CBEE Student Outcome C3.2: Fill Various Roles, and CBEE Student Outcome C3.3: Resolve Conflict. CBEE student outcome descriptions: Students will be able to work effectively in teams with others having different backgrounds (C3.1). Students will be able to fill both leadership and supporting roles in a team (C3.2). Students will be able to define rules for conflict resolution and practice those rules (C3.3).

Outcome	Novice (0 points)	Developing (1 point)	Satisfactory (2 points)	Exemplary (3 points)
1. Students are aware of a variety of contemporary issues involving ethical and professional responsibility in technical fields.	Student is not aware of any standard codes of ethical behavior (e.g., ACS, AIChE, etc)	Student is aware of the existence of the standard codes of ethical behavior	Student understands and can discuss an appropriate standard code of ethical behavior (e.g. ACS, AIChE, etc)	Student understands and abides by the an appropriate standard code of ethical behavior (e.g. ACS, AIChE, etc)
2. Students can conduct and defend an ethical analysis when given a representative ethical/professional situation	Uses personal value system to support actions to the exclusion of all other ethical standards	Uses personal value system to support actions, but confuses personal ethics with professional ethics	Evaluates and judges a situation in practice or as a case study, using personal opinion, perhaps with reference to an appropriate professional code of ethics	Evaluates and judges a situation in practice or as a case study, using facts and an appropriate professional code of ethics
3. Students can identify an ethical/professional situation as requiring ethical analysis.	Evaluates and judges a situation in practice or as a case study using a biased perspective without objectivity	Evaluates and judges a situation in practice or as a case study using personal understanding of the situation, possibly applying a personal value system	Uses personal value system to support actions, but recognizes the existence of professional/corporate ethical standards	Uses personal value system to support actions, but understands the role of professional ethical standards for corporate decisions
4. Students can engage in meaningful discussion of professional ethics	Does not participate in or contribute to discussions of ethics; does not accept the need for professional ethics	Does not take the discussion of ethics seriously but is willing to accept its existence	Regularly participates in class discussions and exercises on ethics and professionalism, but offers little insightful contribution	Regularly participates in class discussions and exercises on ethics and professionalism, making a substantial contribution to the discussion
5. Students demonstrate personal ethics and appropriate professional behavior.	Student has been caught cheating or plagiarizing the work of others; Erroneously blames others for own issues and problems; frequently absent from class and is generally not collegial to fellow students, staff, and faculty	Doesn't recognize the need to take personal responsibility for his/her actions Sometimes exhibits unprofessional behavior; is sometimes absent from class without reason	Takes personal responsibility for his/her actions Is punctual, professional, and collegial; attends classes regularly; understands and complies with UMBC integrity code	Takes personal responsibility for his/her actions Is punctual, professional, and collegial; attends classes regularly, fully abides by UMBC integrity code

Table 4.C-2: Rubric for CBEE Student Outcome C1.5: Broader Impact. CBEE student outcome C1.5 is an element of ABET outcome (f): The ability to recognize ethical and professional responsibilities

Table 4.C-3: Rubric for CBEE Student Outcome C1.5: Broader Impact. CBEE student outcome C1.5 is an element of ABET outcome (h): The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context and ABET outcome (j): A knowledge of contemporary issues.

Performance Characteristic	Unsatisfactory (0 points)	Satisfactory (2 points)	Outstanding (4 points)
1. Students have developed proficiency in a foreign language (ABET h)	No foreign language proficiency	Satisfies the UMBC general foundation requirement for proficiency in a foreign language at the 201 level or higher	Exceeds the UMBC general foundation requirement by having proficiency in multiple foreign languages, a foreign language minor, or a significant overseas experience in a foreign country where English is not the primary language
2. Students have knowledge of cultural issues, especially in global (non-U.S.) cultures (ABET h)	No knowledge of non-U.S. cultures	Satisfies the UMBC general foundation requirements for cultural studies	Exceeds the UMBC general foundation requirements for cultural studies, with coursework representing contemporary non-U.S. cultures or a significant overseas experience in a foreign country
3. Students have basic knowledge of economics (ABET h)	Does not demonstrate the ability to perform engineering economic analysis	Demonstrates ability to perform engineering economic analysis	Demonstrates ability to perform engineering economic analysis AND one of the following: ●passing grade (C or better) in ECON 101 ●AP credit in economics ●Internship experience with a financial institution
4. Students have participated in extracurricular activities providing insight into the impact of engineering in a global, regional, or societal context (ABET h)	No participation in extracurricular activities providing the required insight	Occasional participation in extracurricular activities providing the desired insight (on-campus or off-campus organizations) OR personal experience in an activity on a global, national , regional scale ●Church or service organizations ●Service learning ●Political campaigns ●Volunteer work	Regular participation in or leadership of extracurricular activities providing the desired insight (on-campus or off-campus organizations) OR multiple or extended personal experiences in an activity on a global, national, regional level. ●Church or service organizations ●Service learning ●Political campaigns ●International mission work ●Military service ●Volunteer work ●Study abroad
5. Students have knowledge of environmental issues related to the environmental impact of engineering decisions (ABET h)	Does not demonstrate knowledge of environmental issues or environmental impact of engineering decisions	Demonstrates basic knowledge of environmental issues and environmental impact of engineering decisions OR successful completion (C or better) of 1 course in environmental engineering	Demonstrates basic knowledge of environmental issues and environmental impact of engineering decisions AND one of the following: ●Environmental Engineering and Sustainability Track ●Undergraduate research in environmental engineering ●Internship experience in environmental engineering
6. Students have knowledge of contemporary issues in society and engineering (ABET j)	Does not demonstrate knowledge of contemporary issues related to engineering and society	Demonstrates basic knowledge of contemporary issues related to engineering and society OR acceptable completion (C or better) of one course directly related to contemporary issues in society	Demonstrates basic knowledge of contemporary issues related to engineering and society AND acceptable completion (C or better) of one course directly related to contemporary issues in society

Performance Characteristic	Unsatisfactory (0 points)	Improvement Needed (1 point)	Satisfactory (2 points)	Very Good (3points)
C5.1 Students will be able to identify and define a problem given an open-ended question or situation	Student does not demonstrate the ability or willingness to begin an open-ended problem; demonstrates extreme discomfort with open-ended problems	Student demonstrates the ability to approach and begin an open-ended problem, but becomes overwhelmed, gives up easily or lacks the ability to consider alternate approaches	Student demonstrates the ability to approach an open ended problem, navigate difficulties and generate alternate approaches	Student demonstrates a high level of comfort with open-ended problems, easily generates alternative approaches and is tenacious in his/her approach
C5.2 Students will have the ability to locate tools and information relevant to a problem	Student cannot locate tools or information that have been identified as necessary	Student demonstrates the capacity to locate necessary tools or information but generally relies on others to carry out the task	Student demonstrates the capacity to locate necessary tools or information and frequently carries out the task	Student demonstrates creativity or diligence in locating hard to find tools or information
C5.3 Students will have the ability to assimilate information relevant to a problem	Student cannot identify relevant information or does not demonstrate the ability or willingness to assimilate information relevant to a problem	Student demonstrates the ability to identify relevant information, but sometimes includes extraneous information; student has difficulty integrating information	Student demonstrates the ability to identify relevant information and to determine what information is extraneous; student demonstrates the ability to integrate information	Student demonstrates the ability to identify relevant information and to determine what information is extraneous; student integrates and assimilates information from multiple sources with ease
C5.4 Students will be able to assess their own ability/knowledge to solve a problem and know when to seek help	Student is unwilling to self-assess in a meaningful way; Student is unwilling to seek help from others	Student is willing to self-assess in a meaningful way but self-assessment often lacks alignment with external assessments; Student is willing to seek help from others, but often misjudges when seeking help is appropriate	Student is willing to self-assess in a meaningful way and self-assessment generally aligns with external assessments; student appropriately seeks help from others	Student is self-reflective and demonstrates altered behavior in response to accurate self-assessment; student seeks help as appropriate and demonstrates increasing self-sufficiency

Table 4.C-4: Rubric for CBEE Student Outcome C5.1: Define Problems, CBEE Student Outcome C5.2: Locate Information, CBEE Student Outcome C5.3: Assimilate Information, and CBEE Student Outcome C5.4: Self-Assessment. CBEE student outcome descriptions: Students will be able to identify and define a problem given an open-ended question or situation (C5.1). Students will have the ability to locate tools and information relevant to a problem (C5.2). Students will have the ability to assimilate information relevant to a problem (C5.3). Students will be able to assess their own ability/knowledge to solve a problem and know when to seek help (C5.4).

4.C.2. Example Closing-the-Loop Document

ENCH 225
Closing-the-Loop Report

Student Outcomes and how it was measured

Student Outcome C1.4: Use Modern Tools
Student Outcome C1.5: Understand Broader Impact
Student Outcome C2.1: Solve Open-Ended Problems
Student Outcome C2.3: Design and Conduct Experiments
Student Outcome C2.4: Analyze Data
Student Outcome C3.1: Work Effectively in Teams
Student Outcome C3.2: Fill Various Roles
Student Outcome C3.3: Resolve Conflict
Student Outcome C4.1: Communicate in Writing
Student Outcome C5.1: Define Problems
Student Outcome C5.4: Self-Assessment

Semester/Year: __Spring / 2013___________________
Instructor: ___Enszer ___________________________

Closing-the-Loop: Evidence, Recommendation, Follow-Up, and Results

Student Outcomes ("C's")	***Evidence from Original Assessment***	***Recommendation from that Assessment***	***Follow-Up Implementation***	***Results from Implementation***
C2.4 Analyze Data	29% of the class fell below the minimum standard for being able to analyze data	Increased discussion times which included problem based learning session where lab groups worked for 50 min on an experimental design and analysis while instructors an TAs provided guidance	Change took place for the last two years in ENCH 225L (2015 & 2014)	In the Spring 2015 14% of the class fell below the minimum standard for being able to analyze data

4.C.3. Example Direct Assessment Document

Direct Assessment Summary for ENCH 440, Spring 2015
Outcomes: C1.1 (Foundation Math/Sciences), C1.2 (Proficiency Chemical Engineering Principles), C1.3 (Design Processes), C2.4 (Analyze Data)

Narrative description of the incorporation of Outcomes C1.1, C1.2, C1.3, C2.4 in ENCH 440

ENCH 440 (Chemical Engineering Kinetics) is a required junior level chemical engineering course. The goals of this course are to provide each student with the tools necessary to design reactors and to analyze reaction rate data and elucidate reaction mechanisms. Specifically, students learn how to combine the various tools acquired in transport classes, thermodynamics, chemistry and this class to design reaction schemes for a variety of processes. Students learn basic concepts of chemical kinetics, reactor design and analysis and interpret data taken from isothermal homogeneous reactions in batch, plug flow and perfectly mixed reactors. Students also analyze and interpret data taken from multiple reactions. In the course, students learn to design and analyze isothermal and non-isothermal reactors, simultaneously performing mass and energy balances as needed. By the end of the course, students understand principles of heterogeneous catalysis and design reactors for heterogeneous processes. Students also utilize MATLAB and Polymath as tools to assist in design, modeling and interpretation of data.
The course builds upon students' prior knowledge in thermodynamics and fluid mechanics from ENCH 300 and ENCH 425. From a problem-solving perspective, the course emphasizes a rational, systematic approach to solving problems in reaction kinetics and reactor design using defined algorithms for a variety of problem types. This course therefore lays the groundwork for the capstone design sequence, ENCH 444 and 446 (Process Engineering Economics and Design I and II).

Direct assessment of ENCH 440 is specifically focused on four Student Outcomes. C1.1 (Foundation Math/Science) and C1.2 (Proficiency in Chemical Engineering Principles) are intricately linked and are the primary focus of the course. In every homework and exam question, students must evaluate the problem statement and correctly identify the governing scientific principles applicable to the problem (C1.1). Students must then evaluate the problem to determine what assumptions and equations are appropriate to the given situation and be able to justify their choices (C1.2). Students then apply appropriate mathematical principles and methodologies to solve the resulting equations (C1.1). Since all exam problems are focused on fundamentals in reaction kinetics and reactor design and require mathematical analysis, all target Student Outcomes C1.1 and C1.2. Student Outcome C1.3 (Design Processes) is targeted throughout the semester as the design of reactors is a key element of the course. Specific exam problems in reactor design are used to assess this Outcome. Student Outcome 2.4 (Analyze Data) is targeted in this course through the analysis of kinetic rate data. Students learn how to analyze data to determine reaction rate laws for homogeneous and heterogeneous systems as well as reaction mechanisms in heterogeneous catalysis. Assessment of Outcome 2.4 occurs in both homework and specific exam problems targeted toward this Outcome.

Table 1: Example Direct Assessment Document for ENCH 440.

Outcome	Student Work	Average Score[1]	Max Score	Standard[2]	Number below Standard[3]	Summary
C1.1 Foundations Math/Science	Exams 1-3	70.2	100	60%, based on minimum cutoff score for passing the course with a grade of "C" or better	2 of 64 students, 3% of class	Exam problems target the outcome by focusing on appropriate application of scientific principles and requiring mathematical solutions of the resulting equations.
C1.2 Proficiency Chem Engr Principles	Quizzes 10-12 & Exams 1-3	72.0	100	60%, based on minimum cutoff score for passing the course with a grade of "C" or better	0 of 64 students, 0% of class	All exam problems target the outcome by requiring appropriate engineering judgment in the selection of equations and assumptions and by focusing on the analysis and design of reacting systems. Quizzes focus on engineering principals.
C1.3 Design Processes	Exam 2, Problem 3. HW #2.1 Combined	19 24 43	25 30 55	60%, based on minimum cutoff score for passing the course with a grade of "C" or better	2 of 64 students, 3% of class	Students design single & multiple reactor schemes for both homogeneous and heterogeneous systems throughout the semester. One exam and one HW problem were used to specifically assess this outcome for all individuals.
C2.4 Analyze Data	Exam 2, Problem 4 HW#7 Combined	17 31 48	25 40 65	60%, based on minimum cutoff score for passing the course with a grade of "C" or better	8 of 64 students, 13% of class	Students use rate or reaction data to determine rate law or to deduce reaction mechanism.

[1]Average score across all exams for entire class
[2]The minimum possible score that indicates competency in achieving an outcome
[3]Number of students who did not indicate competency in achieving an outcome, but still passed the course (i.e., achieved a grade of C or better).

CRITERION 5. CURRICULUM

A. Program Curriculum

1. Completed Table 5.A-1

The program curriculum for the three tracks in the chemical engineering undergraduate program at UMBC is given in Table 5.A-1 on the following pages. UMBC operates on a semester system.

Table 5.A-1 Curriculum

B.S. Chemical Engineering – Traditional Track

Semester Number	Course (Department, Number, Title) List all courses in the program by term starting with first term of first year and ending with the last term of the final year.	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[2]	*Curricular Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Average Section Enrollment for the Last Two Terms the Course was Offered[1]
1	CHEM 101 – Principles of Chemistry I	R	*4*				*2017-Spring; 2016- Fall*	*Lecture: 286 Disc: 60*
1	MATH 151 – Calculus and Analytic Geometry I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 161 Disc: 40*
1	ENES 101 – Introductory Engineering Science	R		*3*			*2017-Spring 2016- Fall*	*Lecture:195 Disc: 29*
1	ENGL 100 – Composition – General Education Program Requirement	R			*3*		*2017-Spring 2016- Fall*	*Lecture: 22*
1	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016- Fall*	*-*
2	CHEM 102 – Principles of Chemistry II	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 264 Disc: 70*
2	CHEM 102L – Introductory Chemistry Lab	R	*2*				*2017-Spring 2016- Fall*	*Lecture: 188 Lab: 24*
2	PHYS 121 – Introductory Physics I	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 178 Disc: 30*
2	MATH 152 – Calculus and Analytic Geometry II	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 115 Disc: 30*
2	ENME 110 – Statics	R		*3*			*2017-Spring*	*Lecture: 109*

							2016- Fall	*Disc: 26*
3	CHEM 351 – Organic Chemistry I	R	*3*				*2017-Spring 2016- Fall*	*Lecture: 211*
3	ENCH 215 – Chemical Engineering Analysis Or ENCH 215H – Chemical Engineering Analysis Honors	R		*3*			*2016-Fall 2015- Fall*	*Lecture: 46 Honors: 0 Disc: 92*
3	MATH 251 – Multivariable Calculus	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 139 Disc: 35*
3	PHYS 122 – Introductory Physics II	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 264 Disc: 33*
3	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016- Fall*	*-*
4	CHEM 351L – Organic Chemistry Lab I	R	*2*				*2017-Spring 2016- Fall*	*Lecture: 197 Lab: 18*
4	ENCH 225 – Chemical Engineering Problem Solving and Experimental Design	R		*4*			*2017-Spring 2016- Fall*	*Lecture:32 Lab: 22*
4	MATH 225 – Introduction to Differential Equations	R	*3*				*2017-Spring 2016- Fall*	*Lecture: 56*
4	Advanced Science Elective	SE	*3*				*2017-Spring 2016- Fall*	*-*
4	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016- Fall*	*-*
4	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016- Fall*	*-*
5	CHEM 301 – Physical Chemistry I	R	*4*				*2017-Spring 2016- Fall*	*Lecture: 97*
5	CHEM 311L – Advanced Laboratory I	R	*3*				*2017-Spring 2016- Fall*	*Lecture: 66 Lab: 33*
5	ENCH 300 – Chemical Process Thermodynamics	R		*3*			*2016-Fall 2015- Fall*	*Lecture :44 Disc: 88*
5	ENCH 425 – Transport Process I	R		*3*			*2016-Fall 2015- Fall*	*Lecture: 42 Disc: 84*

5	General Education Program Requirement Elective	SE			*4*		*2017-Spring 2016- Fall*	_
6	CHEM 302 – Physical Chemistry II	R	*3*				*2017-Spring 2016-Spring*	*Lecture: 68*
6	ENCH 427 – Transport Processes	R		*3*			*2017-Spring 2016-Spring*	*Lecture: 43 Disc: 84*
6	ENCH 440 – Chemical Engineering Kinetics	R		*3*			*2017-Spring 2016-Spring*	*Lecture 43 Disc: 85*
6	ENCH 442 – Chemical Engineering Systems Analysis	R		*3*			*2017-Spring 2016-Spring*	*Lecture: 76 Disc: 76*
6	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016- Fall*	_
7	ENCH 437L – Chemical Engineering Laboratory	R		*3*			*2016-Fall 2015-Fall*	*Lab: 14 Disc: 42*
7	ENCH 444 – Process Engineering Economics and Design I	R		*3* √			*2016-Fall 2015-Fall*	*Lecture: 58*
7	ENCH 445 – Separation Processes	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 60*
7	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring 2016-Fall*	_
7	General Education Program Requirement	SE			*3*		*2017-Spring 2016-Fall*	-
8	ENCH 446 – Process Engineering Economics and Design II	R		*4* √			*2017-Spring 2016-Spring*	*Lecture: 28 Disc: 56*
8	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring 2016-Fall*	-
8	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring 2016-Fall*	-
8	General Education Program Requirement	SE			*3*		*2017-Spring 2016-Fall*	-
8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring*	-

							2016-Fall	
8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring* *2016-Fall*	-
TOTALS-ABET BASIC-LEVEL REQUIREMENTS			*51*	*50*	*28*	*[3]*		
OVERALL TOTAL CREDIT HOURS FOR THE DEGREE								
PERCENT OF TOTAL			*39.5%*	*38.8%*	*21.7%*	*NA*		
Total must satisfy either credit hours or percentage	Minimum Semester Credit Hours		32 Hours	48 Hours				
	Minimum Percentage		25%	37.5 %				

1. For courses that include multiple elements (lecture, laboratory, recitation, etc.), indicate the average enrollment in each element.
2. Required courses are required of all students in the program, elective courses are optional for students, and selected electives are courses where students must take one or more courses from a specified group.

Instructional materials and student work verifying compliance with ABET criteria for the categories indicated above will be provided during the campus visit.

Table 5.A-1 Curriculum
B.S. Chemical Engineering – Bioengineering Track

Semester Number	Course (Department, Number, Title) List all courses in the program by term starting with first term of first year and ending with the last term of the final year.	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[2]	Curricular Area (Credit Hours) Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Average Section Enrollment for the Last Two Terms the Course was Offered[1]
1	CHEM 101 – Principles of Chemistry I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 286 Disc: 60*
1	MATH 151 – Calculus and Analytic Geometry I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 161 Disc: 40*
1	ENES 101 – Introductory Engineering Science	R		*3*			*2017-Spring 2016-Fall*	*Lecture: 195 Disc: 29*
1	ENGL 100 – Composition – General Education Program Requirement	R			*3*		*2017-Spring 2016-Fall*	*Lecture: 22*
1	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016-Fall*	-
2	CHEM 102 – Principles of Chemistry II	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 264 Disc: 70*
2	CHEM 102L – Introductory Chemistry Lab	R	*2*				*2017-Spring 2016-Fall*	*Lecture: 188 Lab: 24*
2	PHYS 121 – Introductory Physics I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 178 Disc: 30*
2	MATH 152 – Calculus and Analytic Geometry II	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 115 Disc: 30*

2	BIOL 141 – Foundations of Biology: Cells, Energy and Organisms	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 290 Disc: 24*
3	CHEM 351 – Organic Chemistry I	R	*3*				*2017-Spring 2016-Fall*	*Lecture: 211*
3	ENCH 215 – Chemical Engineering Analysis Or ENCH 215H – Chemical Engineering Analysis Honors	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 46 Honors: 0 Disc: 92*
3	MATH 251 – Multivariable Calculus	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 139 Disc: 35*
3	BIOL 302 – Molecular and General Genetics	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 196 Disc: 27*
3	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016-Fall*	-
4	CHEM 352 – Organic Chemistry II	R	*3*				*2017-Spring 2016-Spring*	*Lecture: 169*
4	ENCH 225 – Chemical Engineering Problem Solving and Experimental Design	R		*4 √*			*2017-Spring 2016-Fall*	*Lecture: 32 Lab: 22*
4	MATH 225 – Introduction to Differential Equations	R	*3*				*2017-Spring 2016-Fall*	*Lecture: 56*
4	BIOL 303 – Cell Biology	R	*3*				*2017-Spring 2016-Fall*	*Lecture: 240 Disc: 30*
4	PHYS 122 – Introductory Physics II	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 264 Disc: 33*
5	CHEM 437 – Comprehensive Biochemistry I	R	*4*				*2016-Fall 2015-Fall*	*Lecture: 158*
5	ENCH 300 – Chemical Process Thermodynamics	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 44 Disc: 88*
5	ENCH 425 – Transport Process I	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 42 Disc: 84*
5	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016-Fall*	-

5	General Education Program Requirement Elective	SE			*4*		*2017-Spring 2016-Fall*	*-*
6	CHEM 303 – Physical Chemistry for Biochemical Sciences	R	*3*				*2017-Spring 2016-Spring*	*Lecture: 117*
6	ENCH 427 – Transport Processes	R		*3*			*2017-Spring 2016-Spring*	*Lecture: 43 Disc: 84*
6	ENCH 440 – Chemical Engineering Kinetics	R		*3*			*2016-Spring 2017-Spring*	*Lecture: 43 Disc: 85*
6	ENCH 442 – Chemical Engineering Systems Analysis	R		*3*			*2017-Spring 2016-Spring*	*Lecture: 76 Disc: 76*
6	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016-Fall*	*-*
7	ENCH 444 – Process Engineering Economics and Design I	R		*3 √*			*2016-Fall 2015-Fall*	*Lecture: 58*
7	ENCH 445 – Separation Processes	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 60*
7	ENCH 482 – Biochemical Engineering	R		*3*			*2016-Fall 2015-Fall*	*Lecture: 15*
7	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring 2016-Fall*	*-*
7	General Education Program Requirement	SE			*3*		*2017-Spring 2016-Fall*	*-*
7	General Education Program Requirement	SE			*3*		*2017-Spring 2016-Fall*	*-*
8	ENCH 446 – Process Engineering Economics and Design II	R		*4 √*			*2017-Spring 2016-Spring*	*Lecture: 28 Disc: 56*
8	ENCH 485L – Bioengineering Laboratory	SE		*4*			*2017-Spring 2016-Spring*	*Lecture: 16 Lab: 16*
8	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring 2016-Fall*	*-*
8	General Education Program Requirement	SE			*3*		*2017-Spring 2016-Fall*	*-*

8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring 2016-Fall*	-
8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring 2016-Fall*	-
TOTALS-ABET BASIC-LEVEL REQUIREMENTS			*57*	*48*	*28*	*[3]*		
OVERALL TOTAL CREDIT HOURS FOR THE DEGREE								
PERCENT OF TOTAL			*42.8%*	*36.1 %*	*21.1 %*	*NA*		
Total must satisfy either credit hours or percentage	Minimum Semester Credit Hours		32 Hours	48 Hours				
	Minimum Percentage		25%	37.5 %				

1. For courses that include multiple elements (lecture, laboratory, recitation, etc.), indicate the average enrollment in each element.
2. Required courses are required of all students in the program, elective courses are optional for students, and selected electives are courses where students must take one or more courses from a specified group.

Instructional materials and student work verifying compliance with ABET criteria for the categories indicated above will be provided during the campus visit.

Table 5.A-1 Curriculum

B.S. Chemical Engineering – Environmental/Sustainability Track

Semester Number	Course (Department, Number, Title) List all courses in the program by term starting with first term of first year and ending with the last term of the final year.	Indicate Whether Course is Required, Elective or a Selected Elective by an R, an E or an SE.[2]	*Curricular Area (Credit Hours)* Math & Basic Sciences	Engineering Topics Check if Contains Significant Design (√)	General Education	Other	Last Two Terms the Course was Offered: Year and, Semester, or Quarter	Average Section Enrollment for the Last Two Terms the Course was Offered[1]
1	CHEM 101 – Principles of Chemistry I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 286 Disc: 60*
1	MATH 151 – Calculus and Analytic Geometry I	R	*4*				*2017-Spring 2016-Fall*	*Lecture 161 Disc: 40*
1	ENES 101 – Introductory Engineering Science	R		*3*			*2017-Spring 2016-Fall*	*Lecture: 195 Disc: 95*
1	ENGL 100 – Composition – General Education Program Requirement	R			*3*		*2017-Spring 2016-Fall*	*Lecture: 22*
1	General Education Program Requirement Elective	SE			*3*		*2017-Spring 2016-Fall*	*-*
2	CHEM 102 – Principles of Chemistry II	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 264 Disc: 70*
2	CHEM 102L – Introductory Chemistry Lab	R	*2*				*2017-Spring 2016-Fall*	*Lecture: 188 Lab: 24*
2	PHYS 121 – Introductory Physics I	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 178 Disc: 30*
2	MATH 152 – Calculus and Analytic Geometry II	R	*4*				*2017-Spring 2016-Fall*	*Lecture: 115 Disc: 30*

2	ENME 110 – Statics	R		*3*			*2017-Spring* *2016-Fall*	*Lecture: 109* *Disc: 26*
3	CHEM 351 – Organic Chemistry I	R	*3*				*2017-Spring* *2016-Fall*	*Lecture: 211*
3	ENCH 215 – Chemical Engineering Analysis Or ENCH 215H – Chemical Engineering Analysis Honors	R		*3*			*2016-Fall* *2015-Fall*	*Lecture: 46* *Honors: 0* *Disc: 92*
3	MATH 251 – Multivariable Calculus	R	*4*				*2017-Spring* *2016-Fall*	*Lecture: 139* *Disc: 35*
3	PHYS 122 – Introductory Physics II	R	*4*				*2017-Spring* *2016-Fall*	*Lecture: 264* *Disc: 33*
3	General Education Program Requirement Elective	SE			*3*		*2017-Spring* *2016-Fall*	*-*
4	CHEM 352 Organic Chemistry II	R	*3*				*2017-Spring* *2016-Spring*	*Lecture: 159*
4	ENCH 225L – Chemical Engineering Problem Solving and Experimental Design	R		*4*			*2017-Spring* *2016-Fall*	*Lecture: 32* *Lab: 22*
4	MATH 225 – Introduction to Differential Equations	R	*3*				*2017-Spring* *2016-Fall*	*Lecture: 55* *Disc: 40*
4	Advanced Science Elective or ENCH 210 Intro to Environmental Engineering	SE	*3*					*-*
4	General Education Program Requirement Elective	SE			*3*		*2017-Spring* *2016-Fall*	*-*
5	ENCH 310 Environmental Chemistry and Biology	R	*3*				*2016-Fall* *2015-Fall*	*Lecture: 11*
5	ENCH 300 – Chemical Process Thermodynamics	R		*3*			*2016-Fall* *2015-Fall*	*Lecture: 44* *Disc: 88*
5	ENCH 425 – Transport Process I	R		*3*			*2016-Fall* *2015-Fall*	*Lecture: 42* *Disc: 84*
5	General Education Program Requirement Elective	SE			*3*		*2017-Spring* *2016-Fall*	_
5	General Education Program Requirement Elective	SE			*4*		*2017- Spring*	_

							2016- Fall	
6	CHEM 303 Physical Chemistry for Biochemical Sciences	SE	*3*				*2017-Spring* *2016-Spring*	*Lecture: 117*
6	ENCH 427 – Transport Processes II	R		*3*			*2017-Spring* *2016-Spring*	*Lecture: 43* *Disc: 84*
6	ENCH 440 – Chemical Engineering Kinetics	R		*3*			*2017-Spring* *2016-Spring*	*Lecture: 43* *Disc: 85*
6	ENCH 442 – Chemical Engineering Systems Analysis	R		*3*			*2017-Spring* *2016-Spring*	*Lecture: 76* *Disc: 76*
6	General Education Program Requirement Elective	SE			*3*		*2017- Spring* *2016- Fall*	_
7	ENCH 437L – Chemical Engineering Laboratory	R		*3*			*2016-Fall* *2015-Fall*	*Lab: 14* *Disc: 42*
7	ENCH 444 – Process Engineering Economics and Design I	R		*3 √*			*2016-Fall* *2015-Fall*	*Lecture: 58*
7	ENCH 445 – Separation Processes	R		*3*			*2016-Fall* *2015-Fall*	*Lecture: 60*
7	ENCH 414 Environmental Biological Processes	SE		*3*			*2016-Fall* *2015-Fall*	*Lecture: 10*
7	General Education Program Requirement	SE			*3*		*2017-Spring* *2016-Fall*	-
6	ENCH 412 Environmental Physicochemical Processes	R					*2017-Spring* *2016-Spring*	*Lecture: 26*
8	ENCH 446 – Process Engineering Economics and Design II	R		*4 √*			*2017-Spring* *2016-Spring*	*Lecture: 28* *Disc: 56*
8	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring* *2016-Fall*	-
8	ENCH XXX – Chemical Engineering Elective (see Table 5.A-2)	SE		*3*			*2017-Spring* *2016-Fall*	-
8	General Education Program Requirement	SE			*3*		*2017-Spring* *2016-Fall*	-
8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring*	-

							2016-Fall	
8	PHED – Physical Education	SE				*[1.5]*	*2017-Spring* *2016-Fall*	-
TOTALS-ABET BASIC-LEVEL REQUIREMENTS			*45*	*56*	*28*	*[3]*		
OVERALL TOTAL CREDIT HOURS FOR THE DEGREE								
PERCENT OF TOTAL			*34.9 %*	*43.4%*	*21.7%*	*NA*		
Total must satisfy either credit hours or percentage	Minimum Semester Credit Hours		32 Hours	48 Hours				
	Minimum Percentage		25%	37.5 %				

1. For courses that include multiple elements (lecture, laboratory, recitation, etc.), indicate the average enrollment in each element.
2. Required courses are required of all students in the program, elective courses are optional for students, and selected electives are courses where students must take one or more courses from a specified group.

Instructional materials and student work verifying compliance with ABET criteria for the categories indicated above will be provided during the campus visi

Table 5.A-2. Description of Elective Courses Listed in Column 2 of Table 5.A-1.

		Undergraduate Enrollment						
Class	Pre-requisites	2011	2012	2013	2014	2015	2016	2017
ENCH 412 Environmental Physicochem. Proc*.	Coreq: ENCH 427; Recommended: ENCH 310	0	18	5	11	5	21	30
ENCH 414 Environmental Biological Processes†	Prereq: ENCH 427, 440; Recommended: ENCH 310	6	5	0	2	12	7	
ENCH 450 Chemical Process Development*	Prereq: ENCH 427, 440	15	17	14	15	10	29	30
ENCH 459 Statistical Design of Experiments*	Prereq: ENCH 427, 440	4	8	6	5	4	NA	NA
ENCH 468 Research Projects*†	GPA ≥ 3.0 and permission from adviser	Sp:1 Fall: 2	Sp:1 Fall: 3	Sp:2 Fall: 1	Sp: 2 Fall: 4	Sp: 1 Fall: 0	Sp: 6 Fall: 1	Sp :6
ENCH 470 Chemical & Env Modeling†	Prereq: ENCH 427, 440	NA	6	4	12	NA	NA	
ENCH 474 Air Pollution†	Prereq: ENCH 427, 440	NA	NA	15	7	11	13	
ENCH 482 Biochemical Engineering†	Prereq: ENCH 427, 440; no bio prereq	24	19	9	10	15	14	
ENCH 484 Biomedical Engineering*	Prereq: ENCH 427, 440; no bio prereq	12	NA	14	NA	12	23	16
ENCH 486 Survey of Sensors and Instrumentation	Prereq: ENCH 427, 440 or instructor permission	23	18	7	25	35	29	

†								
ENCH 489-1/476 Env. Risk Assessment & Remediation†	Instructor permission	11	3	13	17	NA	NA	
ENCH 489-2 Groundwater Hydrology†	Instructor permission	NA	5	4	NA	NA	NA	

†Classes offered in the Fall semester
* Classes offered in the Spring semester

Electives that can be taken that are outside the CBEE Department must satisfy the following:

- Any 3-4 credit course at 200-level or higher in engineering (ENCE, ENME, ENEE) except ENME 217, ENME 320 and ENME 321.
- The course must have an engineering prerequisite.
- Students must meet prerequisite requirements and obtain permission from the course instructor.
- With the exception of ENME 220 and ENME 221, all electives outside ENCH require adviser permission.

2. Curriculum alignment with the Program Educational Objectives.

As discussed in Section 3B, student outcomes and program educational objectives are closely linked. While attainment of the student outcomes does not guarantee achievement of the program educational objectives, we believe that our outcomes define the knowledge, skills and behaviors students should possess by the time of graduation in order to be capable of achieving the program educational objectives. Most outcomes are addressed in multiple courses throughout the program, reinforcing the concepts involved over each student's academic career.

In addition to the engineering courses offered through the CBEE Department, mathematics/science and general education courses also support the program educational objectives. All math and science courses in the curriculum contribute to Student Outcome C1.1 (Students will be able to apply knowledge in mathematics and science). Therefore, all mathematics and science courses target Objective C1 (Competency in the discipline). In addition, the science laboratory courses support Student Outcome C2.3 (Students will be able to design and conduct experiments in order to obtain appropriate data for evaluation of an engineering problem) and Student Outcome C2.4 (Students will be able to analyze and interpret data in order to solve engineering problems). As a result, the laboratory courses target Program Educational Objective C2 (Critical thinking).

Within the general education requirements, students are required to take English 100 (First-Year Composition). Technical writing has been incorporated into several ENCH courses (i.e., ENCH 225, 437L, ENCH 468, and 485L) by altering them to be Writing Intensive (WI) courses. The main purpose of a Writing Intensive course is to engage students in a substantial writing effort within their chosen discipline. Writing intensive courses are also required to achieve the following:

- Engage students in writing as a skill for critical inquiry and/or scholarly research
- Require students to write frequently in and/or out of class
- Provide useful feedback to students regarding their writing
- Discuss the work students are doing as writers at various points during the term

Writing intensive courses support Student Outcome C4.1 (Students will be able to communicate effectively in written form) and thereby target Objective C4 (Communication). These courses support Student Outcome C4.1 (Students will be able to communicate effectively in written form) and thereby target Objective C4 (Communication). In addition, students must pass a language course at the 201 level or demonstrate competency in a foreign language at this level, further supporting Objective C4 (Communication). General education requirements also include three courses in arts and humanities, three courses in social science, and one course in culture/language. These courses are all electives and therefore cannot be explicitly mapped to our program educational objectives. However, in general, these electives support Student Outcome C1.5 (Students will have an elementary knowledge of the contemporary issues including an understanding of professional and ethical responsibility, sustainability, health and safety and the impact of engineering solutions in a global, economic, environmental and societal context).

3. The curriculum and its associated prerequisite structure support the attainment of the student outcomes.

The curriculum directly maps to our student outcomes as described in detail above and in Section 4 (Criterion 4) of this self-study. The curriculum is highly structured leading to a linear progression through the courses (see flowcharts shown in this section below). All prerequisite courses must be passed with a grade of "C" or better to move on to the next course(s) in the sequence. Significant care is taken during the advising process to ensure that students do not move forward in the curriculum without meeting all prerequisites.

The highly structured sequencing of courses allows us to scaffold student learning both in specific course content and with respect to skill development. While all outcomes are targeted throughout the curriculum, we carefully scaffold student learning through the prerequisite structure. For example, enrollment in the capstone chemical process design course and attainment of Student Outcome C1.3 (Students will be able to design a system, component, or processes using chemical engineering principles to meet desired needs within realistic constraints) requires that students have a knowledge of many content areas including material and energy balances (provided by ENCH 215), thermodynamics (provided by ENCH 300), transport phenomena (provided by ENCH 425 and 427), reaction kinetics and reactor design (provided by ENCH 440), separation processes (provided by ENCH 445) and engineering economics and design (provided by ENCH 444). Therefore, these courses are all part of the prerequisite structure and must be passed with a grade of "C" or better prior to enrolling in ENCH 446 (Process Engineering Economics and Design II). This course content scaffolding occurs over a period of six semesters supporting the ultimate attainment of Student Outcome C1.3.

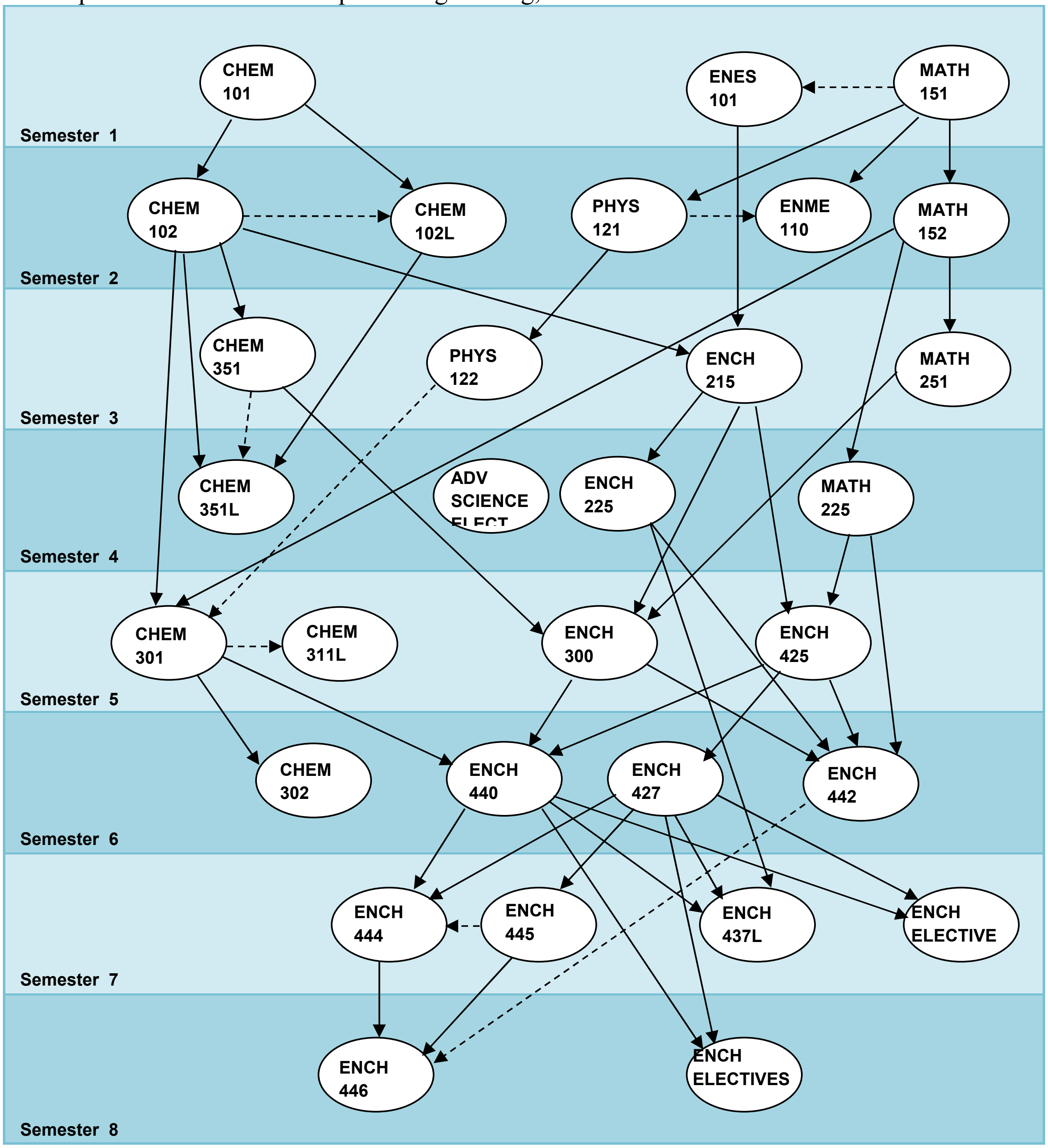
We also simultaneously scaffold student skill development through the prerequisite structure. Again using the example of the senior capstone design course, it is unreasonable to expect students to design a chemical process within realistic constraints if they have never before been faced with open-ended problems or simpler, more limited design experiences. Therefore, these skill sets are targeted and developed in a variety of courses throughout the curriculum leading up to capstone design including Introductory Engineering Science (ENES 101, where an open-ended design project is included where students learning how to apply a rational design process to a problem), Chemical Engineering Analysis (ENCH 215, where student solve open-ended project), Chemical Engineering Problem Solving and Experimental Design (ENCH 225, where students solve open-ended problems), Transport Phenomena I and II (ENCH 425 and ENCH 427, where students complete open-ended design projects), Chemical Engineering Kinetics (ENCH 440, where students design a chemical reactor), Separation Processes (ENCH 445, where students design a separation process unit), and Process Engineering Economics and Design I (ENCH 444, where students learn about the elements involved in the design of a chemical process). This scaffolding of skill sets and abilities ultimately supports the attainment of Student Outcome 1.3. In summary, the overall prerequisite structure directly supports the attainment of our student outcomes.

4. Flowcharts of prerequisite structure

The following three flowcharts illustrate the prerequisite structure of the program's required courses in the three tracks that constitute the program.

B.S. Chemical Engineering - Traditional Track

Prerequisite Flow Chart of Required Engineering, Math & Science Courses

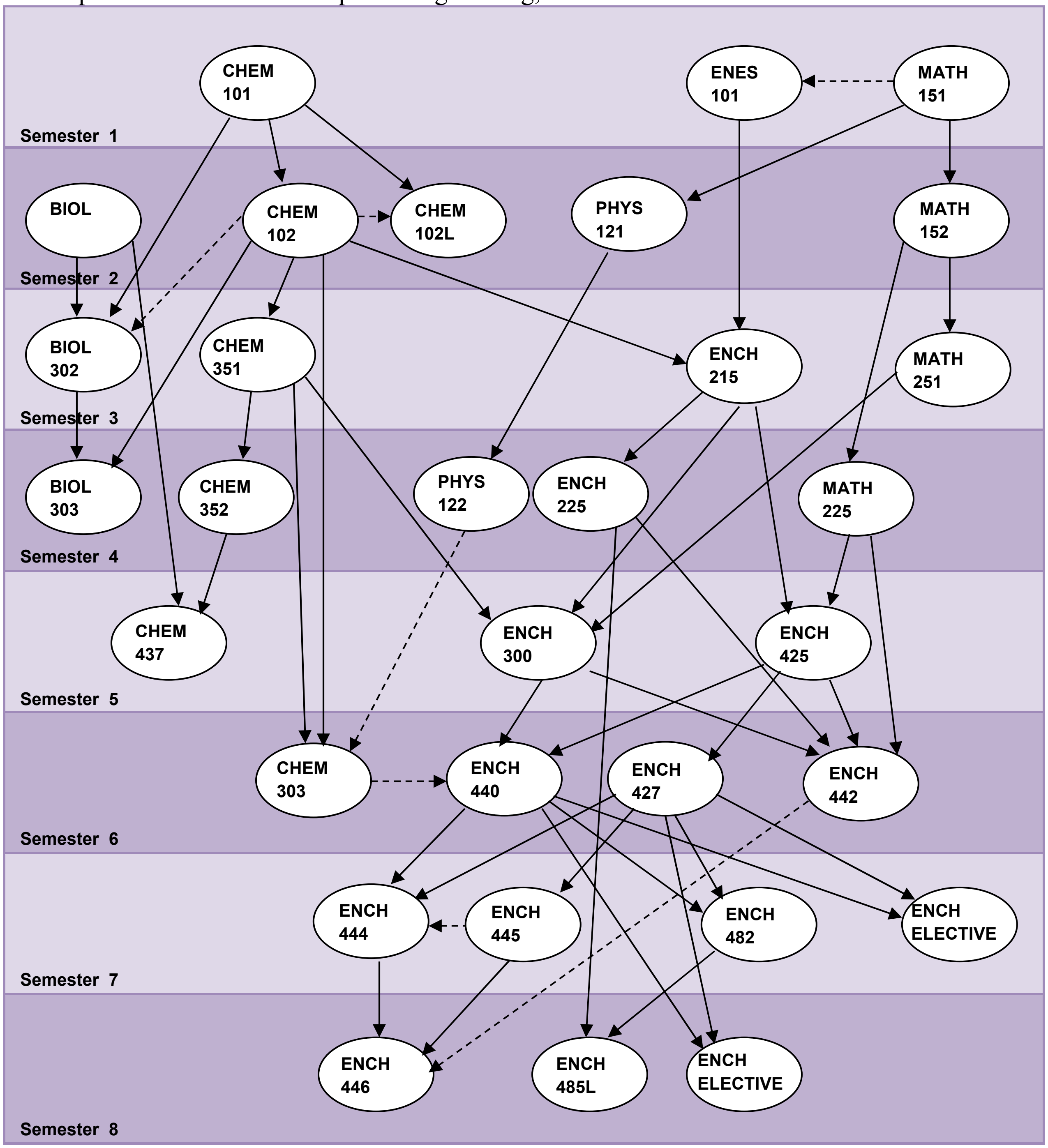


Prerequisite: ———▸

Pre or Co-requisite: - - - -▸

B.S. Chemical Engineering – Biotechnology/Bioengineering Track

Prerequisite Flow Chart of Required Engineering, Math & Science Courses

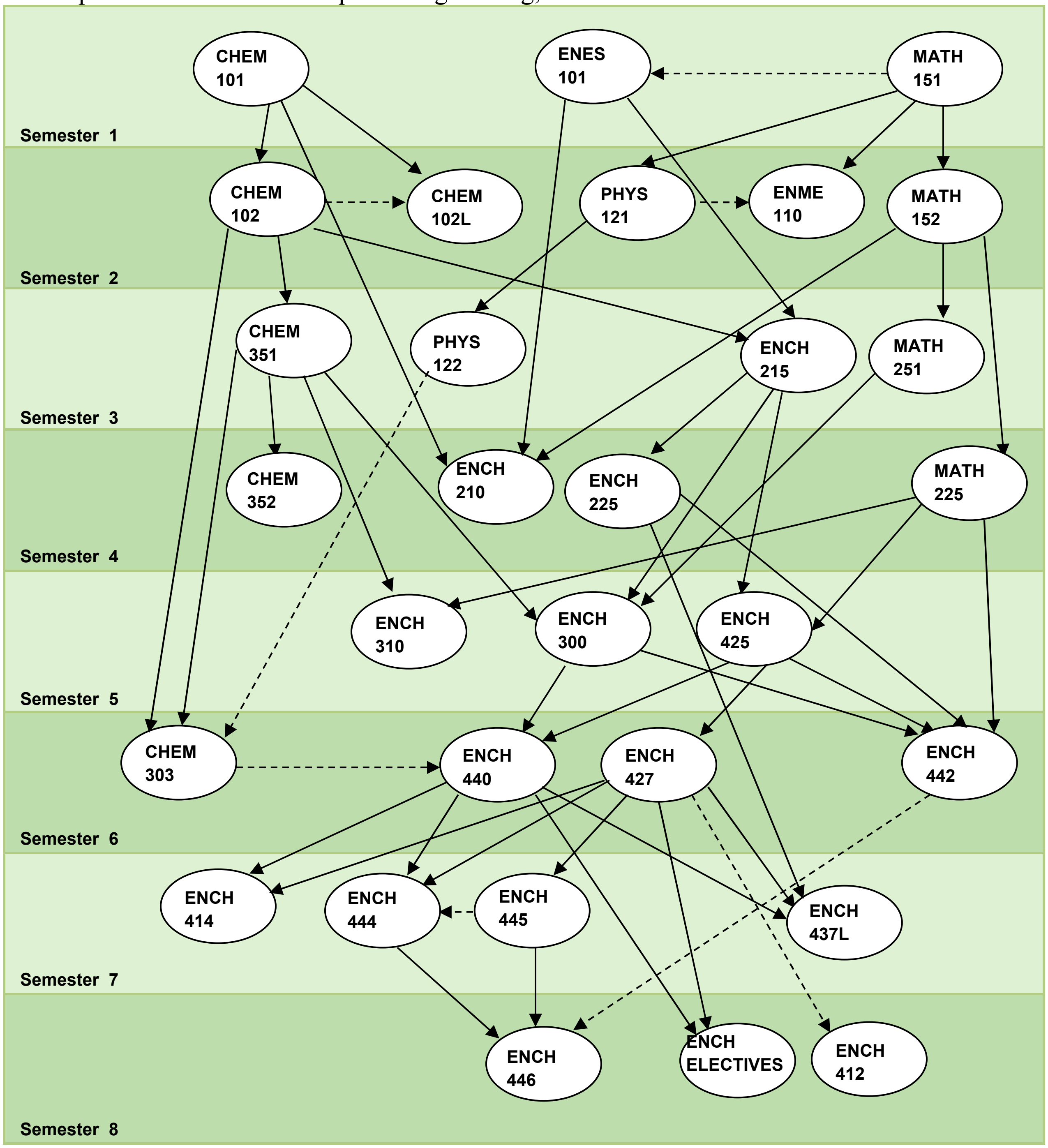


Prerequisite: ⟶

Pre or Co-requisite: - - - -▸

B.S. Chemical Engineering – Environmental Engineering Track

Prerequisite Flow Chart of Required Engineering, Math & Science Courses



Prerequisite:

Pre or Co-requisite:

5. Requirements in terms of hours and depth of study in each subject area.

Our program meets or exceeds the specific requirements for each curricular area outlined in Table 5.A-1 in terms of hours and depth of study. Tables 5.A-3a, 5.A-3b, and 5.A-3c detail the specific credit hours and depth of study for the traditional, biotechnology and bioengineering, and environmental and sustainability tracks.

Table 5.A-3a Breakdown of Credit Hours for Traditional Track

Curricular Area	**Credit Hours**	**ABET Mi Credit Hours**	**Depth of Study**
Math & Basic Sciences	51	32	The traditional track exceeds the ABET minimum credit requirement by 19 credit hours. Students must take a 4 course sequence in mathematics (through differential equations, 15 cr), 8 courses in chemistry including 3 laboratory courses (general, organic and physical, 25 cr) , a 2 course sequence in physics (8 cr) and 1 advanced science elective (3 cr).
Engineering Topics	50	48	The traditional track exceeds the ABET minimum credit requirement by 2 credit hours. Students take an 8 semester, 13 course required engineering sequence beginning in the first semester of the freshman year and culminating with a 2 course engineering design sequence (41 cr). In addition to the required engineering courses, students take 3 engineering electives (9 cr).
General Education	28	Not specified	Students are required to take a minimum of 28 credits of general education courses. This includes 1 English writing courses (3 cr), 3 social science electives (9-10cr), 3 arts/humanities electives (9-10 cr), 1 culture/language course (3 cr) and a language course at the 201 level (3 cr). Students may bypass the 201 level language course requirement by passing a proficiency exam or taking 4 years of a single language in high school.

Table 5.A-3b Breakdown of Credit Hours for Biotechnology and Bioengineering Track

Curricular Area	**Credit Hours**	**ABET Mi Credit Hours**	**Depth of Study**
Math & Basic Sciences	57	32	The biotechnology and bioengineering track exceeds the ABET minimum credit requirement by 25 credit hours. Students must take a 4 course sequence in mathematics (through differential equations, 15 cr), 7 courses in chemistry including 1 laboratory course (general, organic, physical and biochemistry, 23 cr) , a 2 course sequence in physics (8 cr) and a 3 course sequence in biology (11 cr).
Engineering Topics	48	48	The biotechnology and bioengineering track meets the ABET minimum credit requirement. Students take an 8 semester, 13 course required engineering sequence beginning in the first semester of the freshman year and culminating with a 2 course

			engineering design sequence (42 cr). In addition to the required engineering courses, students take 2 engineering electives (6 cr).
General Education	28	Not specified	Students are required to take a minimum of 28 credits of general education courses. This includes one English writing courses (3 cr), 3 social science electives (9-10 cr), 3 arts/humanities electives (9-10 cr), 1 culture/language course (3 cr) and a language course at the 201 level (3 cr). Students may bypass the 201 level language course requirement by passing a proficiency exam or taking 4 years of a single language in high school.

Table 5.A-3c Breakdown of Credit Hours for Environmental/Sustainability rack

Curricular Area	Credit Hours	ABET Mi Credit Hours	Depth of Study
Math & Basic Sciences	45	32	The environmental and sustainability track exceeds the ABET minimum credit requirement by 13 credit hours. Students must take a 4 course sequence in mathematics (through differential equations, 15 cr), 7 courses in chemistry including 1 laboratory courses (general, organic and physical, 19 cr) , a 2 course sequence in physics (8 cr) and 1 advanced science elective (3 cr).
Engineering Topics	56	48	The environmental and sustainability tract exceeds the ABET minimum credit requirement by 8 credit hours. Students take an 8 semester, 16 course required engineering sequence beginning in the first semester of the freshman year and culminating with a 2 course engineering design sequence (50 cr). In addition to the required engineering courses, students take 2 engineering electives (6 cr).
General Education	28	Not specified	Students are required to take a minimum of 28 credits of general education courses. This includes one English writing courses (3 cr), 3 social science electives (9-10 cr), 3 arts/humanities electives (9-10 cr), 1 culture/language course (3 cr) and a language course at the 201 level (3 cr). Students may bypass the 201 level language course requirement by passing a proficiency exam or taking 4 years of a single language in high school.

6. Description of major design experience

The culminating major design experience in the three tracks of the program is the capstone course sequence ENCH 444 and ENCH 446 (Process Engineering Economics and Design I and II). ENCH 444 focuses on the foundation of process design and includes topics such as engineering economics, P&IDs, mechanical integrity, instrumentation and controls, and operational considerations and safety. In ENCH 446 student build upon the material learned in ENCH 444. In particular, they perform a market analysis and establish the economic constraints of their process as well as perform a complete plant design in a team-based environment. Students are required to use Aspen (or an equivalent software system) for their design, but are also encouraged to use other programming tools such as MATLAB and Excel to assist in their preliminary calculations. Safety is a primary design criterion and students must demonstrate that their designs meet safety standards. The instructor sets up the course much like a design firm, where there are milestones to be met each week, and a mixture of oral and written reports are submitted that describe the progress of the design. Students are broken up into teams chosen to balance ability, leadership skills, and work ethic. Individuals and groups receive detailed and constructive feedback from the instructor and teaching assistants from two perspectives: (1) professional growth and (2) chemical engineering competency. Roles within the group are varied periodically during the semester. Groups are graded on both the quality of their design and their ability to work as a team and resolve conflicts.

In 2014, a new structure for the ENCH 446 course was introduced where each week two faculty members in the department participated as consultants for the following six specific themes: (1) material and energy balances, (2) thermodynamics and kinetics, (3) separations, (4) simulation and optimization, (5) process control and safety and (6) environment and society. The faculty consultants met with the teams the week before their presentation and also attended and graded the presentations. This effort incorporated most of the faculty in the department. Student opinions on the process fell into two main categories: (1) the students perceived that they worked harder and this resulted in better designs as they felt more pressure due to being accountable to a higher number of people and specialists in the technical areas being considerd and (2) the students felt that there was some inconsistency in expectations from the persons involved in grading. To account for the student concerns about grading consistency, in 2015 the use of faculty consulting teams continued, but the ENCH 446 course instructor tried to maintain consistency. This was accomplished by having the student design teams meet with the faculty consultants and the course instructor separately, but then during the follow-up presentations the faculty members taking the role of the consultants were present and graded the students. In addition the course instructor was present for every presentation during the semester and also graded the presentations and the rest of the deliverables. In 2016 the enrollment for ENCH 446 increased from 42 to 55, which meant there were 11 student design teams in total. The class was therefore divided into two sections that met at different times. The structure of the course was also changed so that the participating faculty members met with the teams for an "expert consultation," and afterwards provided a grade for the meeting while the course instructor oversaw all the course deliverables. At the end of the semester the students showcase their work with a presentation to the entire faculty as well as the juniors and sophomore students in the department. The final designs are then evaluated for practical and economic feasibility.

Table 5.A-4 shown below indicates how the curriculum prerequisite structure leads to the scaffolding of knowledge and skills acquired in early coursework to prepare students for their major design experience. ENCH 446 is broken down into weekly assignments, and a 1-2 page weekly schedule given to the students at the start of the course describes the topics students should address during each week. These topics are based on the tools and design cases from earlier course work.

Table 5.A-4. Example weekly assignments in ENCH 446.

Week in the Spring semester for ENCH **446**	**Examples of tools and design projects from earlier course work**
Week 2: Identify block flow diagram, perform an overall mass balance. Find major markets, price drivers and annual demand and goal of production	**ENCH 215:** Draw process flow diagrams, perform degree of freedom analysis, solve material balance equations for multiple unit process with recycles and reactions.
Week 3: Process Economics, complete flow diagram and plot plan	**ENCH 444:** Economic analysis of a chemical plant, detailed analyses of materials and operation costs evaluated with respect of impact on safety
Week 4: Find data on kinetics, thermodynamics, and address design issues with reactors	**ENCH 225L:** Data analysis **ENCH 437L**, **485L:** Finding and analyze information and data in the literature
Week 6: Reaction chemistry, application of kinetics to specific reactor design and quantitatively analyze reactor (kinetics, heat transfer, design parameters).	**ENCH 425:** Fluid flow analysis and pumping considerations **ENCH 440:** Design of reactors, finding rate laws, determining pressure drop in reactors **ENCH 427:** Design heat transfer equipment, and solutions to steady and unsteady state molecular diffusion problems dependent on of a chemical reaction
Week 9: Separation processes, including design of distillation columns (including number of plates needed, reflux ratios, column dimensions). Hand calculations of vapor liquid single stage separators, compressors, pumping circuits.	**ENCH 215:** Vapor-liquid equilibrium **ENCH 300:** Vapor-liquid equilibrium **ENCH 445:** Design of separation systems
Final Week Students gather all their design criteria, results and sensitivity analysis, and choose the most relevant information for a final presentation.	**ENES 101, ENCH 427**, **437L**, **444**, **485L** Presentations of projects or experiments

7. Cooperative education is not used to satisfy curricular requirements.

8. Materials available for review during accreditation visit

A variety of materials will be available to the evaluation team including the following:

A. Departmental ABET website.

We use Google Drive as a tool for compilation and collaboration in our ABET preparation efforts. Access to this site will be provided prior to the campus visit. We have all of our ABET information on this site including:

- Description of Program Educational Objectives and Student Outcomes
- All survey instruments, rubrics and analyses

- All Advisory Board information, presentations and reports
- All course syllabi, DA/IDA tables, student exit interviews, etc

Printed copies of the above information will also be available if requested.

B. Course Notebooks: For each course we have a notebook which contains the following:

- ABET syllabus and syllabus given to students during the course
- Written descriptions of assignments and examinations given to students
- Examples of all student work, projects, exams, homework, etc.
- Notebooks Organized by Outcome
- Direct assessment data for each Outcome
- Examples of study work for each Outcome
- Analysis and evaluation of assessment data

B. Course Syllabi

See Appendix A for all course syllabi.

CRITERION 6. FACULTY

A. Faculty Qualifications

A merger occurred between the Chemical and Biochemical Engineering Department and the Civil and Environmental Engineering (CEE) Department during the Spring 2011 semester to create a new department that was called the Chemical, Biochemical, and Environmental Engineering (CBEE) Department. Note that at the time of the merger the CEE Department did not have an undergraduate program. As a condition of this merger, the newly formed department was given permission to search for three new full-time positions. Two new assistant professors (Dr. Lee Blaney and Dr. Christopher Hennigan) and one lecturer (Dr. Josh Enzer) were consequently hired. During the 2014-15 and 2015-16 academic years, Dr. Theresa Good (a full professor), Dr. Enzer (a lecturer) and Dr. Taryn Bayles (a Professor of the Practice) left the department, and Dr. Julia Ross became COEIT Dean. During the 2015-16 academic year, the department hired Dr. Gregory Szeto at the assistant professor level and Dr. Erin Lavik at the full professor level. One assistant professor (Dr. Peng Xu) and one lecturer (Dr. Gautom Das) were hired during the 2016-17 academic year, and one part-time lecturer (Dr. Neha Raikar) was converted to full-time status also during that year. The department also has permission to search for a new assistant professor in the 2017-18 academic year.

For the 2016-17 academic year the department consists of 15 full-time faculty members, which includes 12 tenure/tenure track faculty members and three full-time lecturers. This group of faculty includes Dr. Govind Rao and Dr. Claire Welty, who are also directors of university-wide research centers and who therefore have a reduced teaching and service load. The group of full-time instructional faculty members previously mentioned does not include Dr. Antonio Moreira, a tenured faculty member in the CBEE Department with an administrative appointment as Vice Provost for Academic Affairs. However, Dr. Moreira continues to advise graduate students in the department and also oversees the Certificate in Biochemical Regulatory Engineering program, so he is included in some of the tables of information in this section. The CBEE Department currently also employs one part-time instructor who teaches one course. The number of part-time instructors varies from year to year based on instructional needs.

Each of the full-time faculty members in the CBEE Department has a Ph.D. in chemical engineering, environmental engineering, materials science and engineering, or civil engineering. The part-time instructor in the program has a B.S. degree in chemical engineering and significant experience in industry. Credentials and experience for each faculty member are detailed in Table 6-1 and in the individual CVs shown in Appendix B. CBEE faculty members are highly visible externally (i.e., beyond UMBC). The list given below describes highlights of the notable achievements of the faculty in the 2012-17 time period. Additional notable achievements of the faculty can be found in Appendix B (Faculty Vitea).

Lee Blaney
- NSF CAREER Award, 2017.
- Donald Creighton Memorial Faculty Award, 2015.
- Associate Editor for *Current Pollution Reports*, Springer, 2014-present.

Douglas Frey

- Editorial board member for the journal *Biotechnology and Applied Biochemistry*
- Selected as the 2014 Csaba Horvath Distinguished Lecturer in Chemical Engineering at Yale University.

Chris Hennigan

- NSF CAREER Award, 2015.

Jennie Leach

- Editorial Board of AIMS Bioengineering, 2013-2016

Mark Marten

- Member of the Editorial Board for *Biotechnology and Bioengineering*.
- Previous recipient of NSF CAREER Award.

Brian Reed

- Hackermann Chair of Engineering at UMBC.

Claire Welty

- Science Advisory Board Member, Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt), NSF Engineering Research Center, Stanford University, 2015 - present.
- Consortium of Universities for the Advancement of Hydrologic Science, Inc., UMBC representative, 2012 - present.

All tenure-track faculty members lead active research programs specializing in biochemical engineering, biomedical engineering, or environmental engineering, and participate in both the undergraduate and graduate degree programs. Faculty expertise covers a broad range in the areas of biomaterials engineering, bioprocess engineering, cellular engineering, sensor technology, systems biology, functional genomics and environmental engineering. The CBEE Department is unique in providing the “bio” aspect of chemical engineering since the birth of the department in 1983. Furthermore, since 2001, undergraduate students have had the opportunity of following a traditional chemical engineering track or a biotechnology and bioengineering track. Despite the bipartite structure of the department where the faculty conduct research mainly in either the “bio” or environmental areas, most of the faculty have developed a strong background in the traditional areas of chemical engineering and are able to teach any of the undergraduate courses in the program.

Contacts between the faculty and industry are numerous, and several faculty members (i.e., Drs. Marten and Moreira) have significant industrial experience. In addition, the current part-time lecturer (John Rudesill) has had more than 30 years of industrial experience at W.R. Grace while several members of the faculty, including Drs. Frey, Ghosh, Marten, Moreira, Rao, and Reed, actively consult with industry. Dr. Moreira is also a member of several local industrial organizations. In addition, faculty members meet with the CBEE Advisory Board. Many of the board members have considerable industrial experience and consequently provide an industrial viewpoint on many issues related to the undergraduate program.

B. Faculty Workload

Faculty workload for tenure-track faculty is governed by the CBEE Workload Policy in conformance with the workload requirements set by the University System of Maryland Board of Regents Policy on Workload and Responsibilities. The workload policy is written in terms of an average demand on a faculty member's time. It is understood that there will be differences in workload distribution between some of the faculty members at any given point in time. This distribution may also change with time for an individual faculty member to reflect the progression of a faculty member's career. The CBEE Department Chair authorizes such changes in workload distribution. The department chair also reviews workload expectations of each faculty member annually.

Faculty teaching assignments for the 2016-17 academic year are shown in Table 6-2 along with each person's total activity distribution. The typical distribution of workload for a tenure-track faculty member is 40% teaching, 40% research and 20% service, and for full time instructional faculty the typical distribution is 70% teaching, 10% research, and 20% service. Generally, research active faculty members teach one course each semester, leaving adequate time for research and service activities. The number of traditional courses taught increases for faculty members with less active research programs. In this case, the instructional load will vary from 3-4 traditional classroom courses per year (moderate research activities) up to 5 traditional classroom courses per year (no research activity and no significant courses development activities). Regardless of research activity, faculty members are expected to carry a full service load. In order to account for administrative duties, the teaching load for a research active department chair is reduced to one traditional classroom course per year.

All tenure-track faculty members are expected to establish an active, externally funded research program of outstanding caliber in their areas of expertise. Externally funded research programs should include support for Ph.D. and M.S. graduate students as well as provide funds for equipment, supplies and other costs related to carrying an active research program. Each research active departmental faculty will, on the average, supervise 3 Ph.D. graduate students. Serving as a post-doctoral mentor is also an important function of research active faculty. All faculty members are expected to participate in departmental service activities equivalent to approximately 20% of their time.

C. Faculty Size

Prior to 2011, the overall size of the chemical engineering faculty at UMBC was stable, but small (7 tenured/tenure track faculty and one full time professor of the practice) compared to the national average for chemical engineering departments. The small faculty size presented a challenge to our ability to continue delivering high quality programs in an era of shrinking departmental budgets and growing undergraduate enrollments. The merger of the Chemical and Biochemical Engineering Department and the Civil and Environmental Engineering Department and the hiring of new faculty members has now created an average-sized department (compared to the national average size) and provides much needed stability and redundancy in our teaching capabilities. We are now better poised to meet the needs of our students and constituents.

The CBEE faculty is exceptionally dedicated to the undergraduate program and to student learning, both in and out of the classroom. During of current ABET review cycle the class size in the department has grown to more than 60 graduating seniors from the prior level of typically 25 graduating seniors. Due to the rising class sizes, significant effort has been made to maintain the quality and level of student-faculty interactions. All members of the faculty have scheduled office hours, and are available at other times to meet with students. Faculty-student interactions extend beyond the classroom and include undergraduate research, advising and social activities. Each student meets at least once each semester with his/her adviser to discuss outcomes from the previous semester and to plan strategies for the upcoming term. Additionally, all other faculty members are available for advising undergraduates in terms of research experience and future career opportunities.

The Department of Chemical, Biochemical, and Environmental Engineering maintains a website to aid in communication with students. Part of this website is targeted to provide essential information to the students, such as class schedules, student organizations, and student services, admission requirements, program components and regulations, program education objectives and program student outcomes, and courses offered. To further provide students with up-to-date student-centered tools, many courses have sites on Blackboard where course items such as the syllabi, announcements, homework, and reference materials are posted. These courses include ENES 101 and ENCH 215, 225, 300, 425, 427, 437L, 440, 445 and 446. The ENCH 445 (Separation Processes) course also incorporates a freely available website which is currently one of the most widely used resources on the internet for separation processes education.

D. Professional Development

A variety of professional development opportunities are available on campus for all faculty members. UMBC offers a Faculty Development Center that provides professional development guidance and organizes workshops for faculty on specific teaching topics and other areas of professional development (see http://www.umbc.edu/fdc/). This center houses a library of materials related to faculty development and is available to offer confidential assistance with the development of teaching skills. In addition, various organizations on campus organize professional development workshops for faculty and staff. A central website catalogs available opportunities (http://lib.guides.umbc.edu/c.php?g=24909&p=151723). Finally, the ADVANCE Program organizes a number of professional development activities and workshops targeted toward STEM faculty (http://www.umbc.edu/advance/). These activities provide guidance on various areas related to faculty success including leadership training, communication skills, training for proposal writing and running a research laboratory. Participation in off-campus professional development is also encouraged and financial support for travel and registration is provided by the CBEE Department upon request.

All new faculty members are required to create a Faculty Development Plan in collaboration with the Department Chair and assigned departmental mentor. The plans are reviewed and approved by the Dean and Vice Provost for Faculty Affairs. New faculty members are especially encouraged to take advantage of professional development activities. In particular, all new faculty members are offered the opportunity to participate in the Chemical Engineering Summer School.

A list of significant recent professional development activities for departmental faculty is shown below. Additional professional development activities can be found in Appendix B (Faculty Vitae).

Lee Blaney, Assistant Professor

- 2012, Participant, ASEE Chemical Engineering Summer School, University of Maine.
- 2011-2016, Regular Participant, UMBC Faculty Development Center workshops and seminars.

Mariajose Castellanos, Senior Lecturer

- "Scholarship of Teaching and Learning Discussion Group," FDC UMBC, Baltimore, MD. (January 1, 2012 - Present).
- Workshop, "AAAS Workshop on Communicating Science," COEIT UMBC, Baltimore, MD, United States. (April 10, 2016).
- Training, "Implicit Bias Training," COEIT UMBC, Baltimore, MD. (September 9, 2015).
- Self-Study Program, "Faculty Learning Community Contemplative Pedagogy," FDC UMBC. (August 26, 2014 - May 8, 2015).
- Self-Study Program, "Faculty Learning Community Contemplative Pedagogy," FDC UMBC. (August 26, 2014 - May 8, 2015).
- Conference Attendance, "Wakonse Conference on College Teaching," Shelby, Michigan. (May 22, 2014 - May 27, 2014).
- UMBC Internal Teaching & Learning Symposium, "Provost's Teaching & Learning Symposium," UMBC. (September 12, 2014).
- Workshop, "Teaching Naked: Designing Assignments for More Active Classrooms," Wiley Learning Institute. (February 27, 2014).
- Workshop, "Assessment Techniques for Collaborative Teams," Sloan Consortium. (March 15, 2013 - March 22, 2013).
- FDC Progam, "Making Grading Efficient—Using Peer Response," FDC UMBC, Baltimore, MD. (February 19, 2013).
- Faculty Development Center at UMBC, "Making Grading Efficient—Creating and Using Rubrics," FDC UMBC, Baltimore, MD, USA. (February 5, 2013).

Douglas Frey, Professor

- ABET Commission Meeting, July 13, 2017.

Jennie Leach, Associate Professor

- Workshops by Dr. Barbara Walvoord on teaching Writing Intensive courses (2011).

Brian Reed

- ABET Accreditation Workshop, 2015.

Greg Szeto, Assistant Professor

- 2017, Participant, ASEE Summer School for Chemical Engineering Faculty, North Carolina State University.

E. Authority and Responsibility of Faculty

The faculty members of the CBEE Department play the major role in course creation, modification and evaluation. Specifically, faculty members are responsible for the development and instruction of all CBEE courses. For each assigned courses, the faculty member involved collects and analyzes direct assessment data and other types of input as described elsewhere in this document. If course modifications are needed, the faculty member responsible for the course makes the needed change. In addition, all faculty members participate in CBEE Advisory Board meetings and discussions regarding program-wide changes that span multiple courses. All faculty members also participate in the development of the ABET self-study report by providing course syllabi and direct assessment data every semester as well as updated faculty CVs. The ABET Coordinator role is assigned to a faculty member as his/her primary service responsibility. The ABET Coordinator is a member of the CBEE Undergraduate Committee, which is the faculty group that routinely monitors undergraduate course creation, modification, evaluation, consistency and quality. The ABET Coordinator and Undergraduate Program Director both contribute to the development of the ABET Self-Study document.

The offices of the Dean and Provost are not directly involved in undergraduate course creation, modification or evaluation at the individual course level. However, the Office of the Dean periodically consults with the ABET Coordinators and Department Chairs in the College to discuss accreditation issues and to ensure that all departments are on track with assessment and evaluation processes. Therefore, the Dean's Office functions in an oversight role and also aids in communication between departments in the College. The Dean's Office also provides support in gathering data for the ABET Self-Study and feedback on draft documents. Since the 2005 ABET visit, the Provost's Office has played a role in the insertion of writing into several chemical engineering courses through a Writing in the Disciplines campus-wide initiative. Three departmental courses are now designated as Writing Intensive courses. Finally, the UMBC Undergraduate Council, a standing committee of the UMBC Faculty Senate, must approve all changes in program requirements, credit hours, prerequisites, or development of new courses. These processes, in conjunction with our departmental review processes that occur each year, ensure consistency and quality of the courses taught.

Table 6-1. Faculty Qualifications

Chemical and Biochemical Engineering

Faculty Name	Highest Degree Earned- Field and Year	Rank [1]	Type of Academic Appointment[2] T, TT, NTT	FT or PT[4]	Years of Experience			Professional Registration/ Certification	Level of Activity H, M, or L		
					Govt./Ind. Practice	Teaching	This Institution		Professional Organizations	Professional Development	Consulting/summer work in industry
Lee Blaney	PhD, Env. Eng., 2011	Asst. P.	TT	FT	0	6	6		M	M	L
Mariajose Castellanos	PhD, Chem. Eng., 2005	Lect.	NTT	FT	0	12	12		M	H	L
Gautom Das	PhD, Chem. Eng., 2010	Lect.	NTT	FT	0	1	1		L	L	L
Douglas Frey	PhD, Chem. Eng., 1984	P	T	FT	2	33	24		M	L	M
Upal Ghosh	PhD, Civil and Env. Eng. 1998	P	T	FT	0	17	15		M	L	M
Chris Hennigan	PhD, Env. Eng., 2008	Asst. P.	TT	FT	2	4	4		M	L	L
Erin Lavik	PhD, Material Sci. and Eng., 2001	P	T	FT	0	13	2		M	L	L
Jennie Leach	PhD, Chem. Eng., 2003	Assc. P.	TT	FT	0	12	12		M	L	L

Mark Marten	PhD, Chem. Eng., 1991	P	T	FT	2	23	23		H	L	M
Antonio Moreira	PhD, Chem. Eng., 1977	P	T	FT	8	31	27		M	L	M
Neha Raikar	PhD, Chem. Eng., 2010	Lect.	NTT	FT	4	3	3		L	L	L
Govind Rao	PhD, Chem. Eng., 1987	P	T	FT	0	29	29		M	L	H
Brian Reed	PhD, Civil Eng., 1990	P	T	FT	0	27	15		M	L	H
Greg Szeto	PhD, Cellular and Molec. Medicine, 2010	Asst. P	TT	FT	0	1	1		M	L	L
John Rudesill	BS, Chem. Eng.,1972	Inst.	NTT	PT	39	10	10		L	L	H
Claire Welty	PhD, Civil Eng., 1989	P	T	FT	7	28	16		H	L	H
Peng, Xu	PhD, Chem. and Biolog. Eng., 2013	Asst. P	TT	FT	0	1	1		M	L	L

1. Code: P = Professor Assc. P = Associate Professor Asst. P = Assistant Professor Inst. = Instructor A = Adjunct O = Other

2. Code: TT = Tenure Track T = Tenured NTT = Non Tenure Track

3. The level of activity, high, medium or low, should reflect an average over the year prior to the visit plus the two previous years.

4. At the institution

Table 6-2. Faculty Workload Summary

Chemical, Biochemical, and Environmental Engineering

Faculty Member (name)	PT or FT[1]	Classes Taught (Course No./Credit Hrs.) Term and Year[2]	Program Activity Distribution[2,3]			% of Time Devoted to the Program[5]
			Teaching	Research or Scholarship	Other[4]	
Lee Blaney	FT	Env. Chem. Biol. (ENCH 310, 3 cr., Fall 2016) Chemical Eng. Kinetics (ENCH 640, 3 cr., Sp. 2017)	40%	40%	20%	100%
Mariajose Castellanos	FT	Chem. Eng. Thermodynamics (ENCH 300, 3 cr., Fall 2016) Proc Eng. Econ and Design II (ENCH 446, 4 cr., Sp. 2017) Chem. Eng. Thermodynamics (ENCH 610, 3 cr., Fall 2016)	60%	10%	30%	100%
Gautom Das	FT	Proc. Eng. Econ. and Design I (ENCH 444, 3 cr., Fall 2016) Chem. Eng. Lab., (ENCH 437L, 3 cr., Fall 2016) 75% effort Biomed Eng. (ENCH 484/693, 3 cr., Sp. 2017) (50% effort) Transport Phenomena (ENCH 640, 3 cr., Sp. 2017)	70%	10%	20%	100%
Douglas Frey	FT	Separation Processes (ENCH 445, 3 cr., Fall 2016)	20%	40%	40%	100%
Upal Ghosh	FT	Env Biol Processes (ENCH 414, 3 cr., Fall 2016)	40%	40%	20%	100%

		Transport II: Heat and Mass Transfer (ENCH 427, 3 cr., Sp. 2017)				
Chris Hennigan	FT	Air Pollution (ENCH 474, 3 cr., Fall 2016) Env. Physicochem. Processes (ENCH 412, 3 cr., Sp. 2017)	40%	40%	20%	100%
Erin Lavik		Biochemical Engineering Laboratory (ENCH 485L, 4 cr. Sp. 2017)	20%	60%	20%	100%
Jennie Leach	FT	Chem. Eng. Analysis (ENCH 215, 3 cr., Fall 2016) Biomed Eng. (ENCH 484/693, 3 cr., Sp. 2017) (50% effort)	40%	40%	20%	100%
Mark Marten	FT	Chem. Eng. Kinetics (ENCH 440, 3 cr., Sp. 2017)	20%	40%	40%	100%
Antonio Moreira	FT	Reg Issues Biotech (ENCH 660, 3 cr., Fall 2016) QC/QA Biotech Prod (ENCH 664, 3 cr. Fall 2016) GMP Bioprocess (ENCH 662, 3 cr., Sp. 2017) Biotech GMP Facility Des (ENCH 666, 3 cr., Sp. 2017)	10%	10%	80%	20%
Govind Rao	FT	Survey Sensors and Inst (ENCH 486/686, 3 cr., Fall 2016)	20%	70%	10%	100%
Neha Raikar	FT	Chem. Eng. Prob. Solving Lab. (ENCH 225L, 3 cr., Fall 2016) Transport I: Fluids (ENCH 425, 3 cr., Fa. 2016) Chem. Eng. Prob. Solving Lab. (ENCH 225L, 3 cr., Sp. 2017) Chem. Proc. Control Safety (ENCH 442, 3 cr., Sp. 2017)	70%	10%	20%	100%
Brian Reed	FT	Chem. Eng. Lab., (ENCH 437L, 3 cr., Fall 2016) 25% effort Intro. Eng., (ENES 101, 3 cr., Sp. 2017)	40%	40%	20%	100%
John Rudesill	PT	Chem. Process Development (ENCH 450/650, 3 cr., Sp.	100%	0%	0%	100%

		2017)				
Gregory Szeto	FT	Chem. Eng. Prob. Solving Lab. (ENCH 225L, 3 cr., Sp. 2017)	20%	60%	20%	100%
Claire Welty	FT	None	0%	70%	30%	50%
Peng Xu	FT	Biochemical Eng. (ENCH 482/682, 3 cr., Fall 2016)				

1. FT = Full Time Faculty or PT = Part Time Faculty, at the institution
2. For the academic year for which the self-study is being prepared.
3. Program activity distribution should be in percent of effort in the program and should total 100%.
4. Indicate sabbatical leave, etc., under "Other."
5. Out of the total time employed at the institution.

CRITERION 7. FACILITIES

A. Offices, Classrooms and Laboratories

1. Offices (Administrative, Faculty, Clerical, Teaching Assistants)

The CBEE Department is housed in two buildings. Ten faculty members, with their respective research laboratories, are located in the Engineering building. The Technology Resource Center (TRC) houses five faculty members along with their research laboratories. Each faculty member has a private office of at least 100 square feet. Teaching and research assistants are also provided office/desk space. In the Engineering building, graduate student desks are located in larger rooms separated by room dividers. In the TRC building, graduate students share smaller offices. The departmental administrative offices are located in the Engineering building and provide conference room space as well as offices for the Department Chair and administrative assistants. All individual offices are equipped with personal computers. Printing/copying/fax equipment is shared in each location and provided in a centralized space. Office space and equipment are adequate to support the attainment of the Program Educational Objectives and Student Outcomes.

2. Classrooms

UMBC maintains classrooms throughout the campus. As part of course scheduling, classrooms are centrally assigned based on course needs and enrollment. Classroom space supports an atmosphere conducive to learning and is adequate to support the Program Educational Objectives and Student Outcomes. The UMBC Division of Information Technology (DoIT) also provides technology and services for classroom instruction. More than 60 percent of all UMBC registrar-controlled classrooms are equipped with fixed projection systems. Mobile technology carts can be delivered upon request to other classrooms on a “first come, first served” basis. In addition, students and faculty can borrow video cameras for use in assignments. The Blackboard Course Management System (CMS) is used by more than 1,000 courses and 350 organizations every semester. Nearly all courses in the CBEE Department use Blackboard for posting materials and organizing grades. Finally, UMBC utilizes the Classroom Performance System (CPS) “clickers” by eInstruction.com to support instant student feedback to questions posed by faculty in PowerPoint or impromptu question slides. Results can be anonymous to support assessment of sensitive subjects, or identified by student userid and imported into a corresponding Blackboard class.

3. Laboratories

The departmental laboratory facilities for both teaching and research are of high quality and support the attainment of the CBEE Program Educational Objectives and Student Outcomes. Facilities for a sophomore-level course and the two senior-level laboratories are described below.

The laboratory section of ENCH 225 is held in Engineering 335. This room is designed as a flexible wet laboratory teaching space to accommodate 25 students and has a seating area with tables and whiteboard for discussion as well as bench space for hands-on activities. The two senior laboratories, ENCH 437L (fall) and 485L (spring) are run in Engineering 334, which provides approximately 770 ft^2 of space specific for this purpose. The laboratory contains all standard facilities, including 120 and 240 volt electrical power, hot and cold water, and pressurized air. Safety equipment includes an eye wash station, a fire extinguisher, and seveal first aid kits. For safety reasons, the teaching laboratory is only available to students during scheduled course times. Over $100,000 of departmental funds have been invested in equipment purchases for these labs since 2006. Appendix C contains a list of major instructional and laboratory equipment. The CBEE Department does not maintain any computing facilities. Instead, campus computing resources are utilized when needed as described below.

B. Computing Resources

Over 2,100 wireless access points cover the campus and provide wireless connectivity throughout all academic buildings and residence halls. UMBC has been increasing its wireless coverage to outside areas with seating to better support collaboration. Internet access is provided to the campus through a pair of 10Gb/s connections to the regular Internet and a 100Gb/s connection to Internet2 designed to support research. UMBC was an early member of Internet2 and has been a leader in supporting advanced networks on campus. Recently, as part of an NSF grant under the campus cyberinfrastructure program, we deployed what the NSF refers to as a science DMZ to support high-speed file sharing for researchers.

DoIT provides computational support to the campus and the college of Engineering. For general programming courses we have three Linux servers providing shell access to students. These three Linux servers each have 8 cores and 24Gb of RAM. In addition, every workstation computer in our labs runs our instructional Linux distribution in a virtual machine available on the workstation. These servers provide support for most of the Computer Science courses requiring Unix.

DoIT provides an array of computing services and IT support for use in teaching, research, and administration. UMBC students, faculty, and staff receive a computer account to myUMBC, a campus web-based portal that provides access to personal information and tools, including e-mail, file saving and sharing, and personal web pages. The myUMBC portal provides personalized content, business services, and a link to Blackboard, our learning management system that supports teaching and learning. Students can register for classes, retrieve grades, check status of accounts, create personal web pages, and retrieve their e-mail from anywhere in the world. Additionally, faculty and staff use myUMBC to access various business-related services. UMBC utilizes PeopleSoft to fulfill our human resources, financial, and student administration needs.

For research, or specialized instructional needs, DoIT provides support for a campus HPC environment with a 324-node distributed-memory cluster named Maya. The newest part of the cluster is the 72 nodes with two eight-core 2.6 GHz Intel E5-2650v2 Ivy Bridge CPUs with

64Gb memory that includes 19 hybrid nodes with two modern NVIDIA K20 GPUs (graphics processing units) designed for scientific computing and 19 hybrid nodes with two cutting-edge 60-core Intel Phi 5110P accelerators. For advanced computation or data science courses we have a hadoop cluster available with 32 nodes (64 CPUs and 128 cores) where each node has 13Gb of RAM as well as a server running the Jupyter software for data science notebooks. Additionally, DoIT provides facilities support for the Center for Hybrid-Multicore Productivity Research (CHMPR), a CSEE resource for data science and computation.

DoIT currently employs 77 full-time staff and approximately 100 student staff. DoIT takes great pride that approximately 60% of its full-time staff are UMBC alumni. DoIT is organized into five units:

- DoIT’s Business Systems Group (BSG) develops, implements, and maintains UMBC’s key information systems, including our administrative databases. These include various third-party vendor solutions that support human resources, financial transactions, and student information (all PeopleSoft), document imaging for applications and records (ImageNow), and analytics and reporting (Blackboard Analytics). BSG also operates the service management system for the campus (Request Tracker) and online Forms (DocuSign).
- DoIT’s Instructional Technology and New Media group supports faculty across all delivery modes in the effective integration of instructional technology into their courses. This group also partners with the faculty development center on the effective use of technology to support pedagogical change and works closely with College of Engineering faculty seeking to introduce flipped classrooms or team-based learning into their course. One example of collaboration with faculty is an experiment on a hybrid course redesign program called Alternate Delivery Program (ADP), designed to support teaching in the summer or winter semester. In addition, this group’s New Media Studio supports faculty use of digital storytelling in several classes. Instructional Technology oversees the Technology Support Center (TSC) that provides support services to the faculty, staff, and students. The TSC is located in the library and is the front line in addressing support questions that arise.
- DoIT’s Enterprise Infrastructure and Support group’s Classroom Technology unit provides traditional infrastructure services such as desktop support, Unix, Email, Windows, campus networking, and wireless, as well as support for classroom technology in all registrar-controlled classrooms. These services manage almost two petabytes of local storage and handle the oversight of our cloud services such as Google Apps for Education and Box, both of which provide unlimited storage to members of UMBC. Classroom Technology works closely with the colleges on the technology design for new or updated classrooms. In addition, this department oversees all of our computer teaching labs as well as support for our virtual lab. The virtual classroom lab allows any member of the community to connect through the web and get access to the same specialized software running on our lab environment from their personal computer.
- DoIT’s Office of the Chief Information Security Officer and Communications group is responsible for campus cybersecurity and telecommunications. The cybersecurity mission focuses on securing our administrative and research data and making certain that we are following best practices in keeping data secure. For research data, the

CISO works closely with the Vice President of Research and our Institutional Review Board (IRB) within Sponsored Programs. In addition to cybersecurity, this group oversees wiring and phone service for the campus.

- DoIT's Office of the CIO is responsible for the internal operations and administration. DoIT and the College of Engineering jointly support the College of Engineering Business Service Center for basic administration tasks such as payroll and accounting.

In collaboration with University System of Maryland (USM), UMBC has several software site license agreements. All faculty and staff computer machines are covered by USM's Microsoft License and Microsoft Virus protection. Additionally, UMBC has negotiated hardware pricing with Dell and Apple computers (available through the UMBC Campus Bookstore) that are below regular prices. UMBC also offers special discounts on several software applications. A listing of all campus site licenses is available through myUMBC. Some of the most popular are: Apple Mac OS X and XCode Developer, Microsoft Windows and Office Suite. Several mathematics/statistics programs are also available, including Oracle, SAS, SPSS, Maple, Mathematica, MATLAB, Java, C / C++, Alias, FORTRAN, and specialized engineering software, including ABAQUS (HKS Software), AutoCad, COMSOL Multiphysics and Pro-Engineer.

Furthermore, the College of Engineering and IT maintains a computer lab (ITE 238) that is used by the freshman engineering class, ENES 101. The CBEE and Mechanical Engineering Departments also use this classroom for instruction. The chemical engineering courses that have utilized this computer lab include ENCH 215, 225, and 446. Software maintained on these personal computer facilities includes AutoCAD, Aspen, Pro-E, MS Word, WordPerfect, MS Excel, MS PowerPoint, Maple, MATLAB, Mathematica, SAS, COMSOL Multiphysics, and Polymath. Scheduling of ITE 238 is handled through the Dean's Office in the College of Engineering and Information Technology. In addition, UMBC has available a Virtual Desktop Environment (VDE) system which permits students to access all the software normally available in the ITE 238 computer lab in a virtual environment on their own personal computers at any time and at any location. Dedicated computers are also used in various laboratory experiments in the unit operations laboratory for data acquisition and process control purposes.

Table 7.B-1. Student computer facilities

UMBC DoIT Computer Lab Campus Locations		
Location	**Type**	**Size**
ENG* 021 and 021a	Walk-In, open Lab Win 10 and Mac OS with Data Projector	26 Win10/Linux PCs, 26 iMacs/Win10/Linux
ENG 104	Win 10/Linux Lab with Data Projector	24 Student PCs with 1 Instructor
ENG 104a	Win 10/Linux Lab with Data Projector	20 Student PCs with 1 Instructor
ENG 122	Win 10/Linux Lab with Data Projector	27 Student PCs with 1 Instructor
ENG 122a	Win 10/Linux Lab with Data Projector	24 Student PCs with 1 Instructor
ENG 333	Mac OS/Win 10/Linux Lab with Data Projector	31 Student PCs with 1 Instructor
ENG 336	Mac OS/Win 10/Linux Lab with Data Projector	27 Student iMacs with 1 Instructor
Library 7th Floor	Mac OS and Win 7 open space	30 PC's and 30 iMacs

*Engineering Building

C. Guidance

Students in the program are provided appropriate guidance regarding the use of the tools, equipment, computing resources, and laboratories by the course instructors and teaching assistants (TAs). All TAs receive laboratory safety training upon entering the department. The departmental engineering technicians work closely with laboratory instructors and TAs to ensure a safe learning environment.

D. Maintenance and Upgrading of Facilities

The CBEE Department employs two full-time engineering technicians who install, maintain and manage laboratory equipment for the educational and research programs. The laboratory instructor initiates equipment acquisition. If new equipment is needed, the instructor makes the request directly to the CBEE Department Chair. Decisions on acquisition are made based on need and availability of resources. If available resources are not sufficient, the chair works with the instructor to develop a multi-year plan. If the plan involves rollover of surplus budget dollars into future fiscal years, the Dean of the College is included in the planning process.

E. Library Services

The Albin O. Kuhn Library & Gallery serves the information needs of UMBC, including resources such as books, journals, and other media (in both hardcopy and online formats); services (assistance, instruction as well as purchasing, indexing, and cataloging resources); and online access to resources. The Library employs 25 FTE professional librarians/ professional staff, 36 FTE support staff, and 40+ student assistants to provide support to UMBC and COEIT. The Library is open seven days per week (94 service hours per week) during the academic year, 69 hours per week during January and interim breaks, and 73 hours per week during Summer sessions.

Engineering print collections are housed at the Library, which is centrally located on campus. The Library subscribes to more than 3874 individual subscriptions to current magazine, journal, and newspaper titles, which are held in the Serials department located on the second floor of the Library. In addition, the Library has access to over 34,000 fulltext journal titles through subscription databases. The Serials Department also holds more than 163,800 bound volumes of past journal issues and more than 800,000 pieces of microform. All materials are in open stacks.

Library search is available through UMBC's catalogusmai and AOK OneSearch, which searches across databases and the library catalog to locate articles, books, videos and more. Access to the library catalog includes the collections of the 16 libraries on the 12 campuses of the University System of Maryland, as well as three affiliated institutions of higher education in Maryland. Many materials not available in UMBC's collection can be requested from other USMAI campuses through the catalog. Standard reference services, largely provided by professional Librarians, are available from the Library Reference Desk and through the Library's web site via chat, e-mail, or phone. Each academic department is assigned a subject liaison from the Reference department, who serves as the main contact for research or instruction to that academic department. Reference/liaison librarians can help faculty or students with general or complex search strategies in both interdisciplinary and subject specific databases. Library Instruction is provided by the Library faculty, including a science reference librarian.

The library offers subject guides for various departments and subject areas to guide patrons to the databases and other resources available. Of particular interest to COEIT would be the workshops and tutorials on topics such as how to conduct a preliminary U.S. patent search, how to create an academic research poster, and how to utilize web-accessible citation managers.

In addition to the library catalog, the library subscribes to many engineering and technology e-journal archives, full-text databases, and catalogs that benefit COEIT, including the ACM Digital Library, IEEE Xplore, SciFinder, Science Direct, Web of Science, SIAM journals, SpringerLink, ACM journals, JSTOR, the GPO Monthly Catalog and WorldCat. A full list of print and electronic journals available can be located via the Library's web site, including a separate listing for engineering topics. UMBC has also added a discovery system, EDS (Ebsco Discovery Service), to allow users to search a wide variety of databases and e-journals simultaneously.

COEIT faculty under the guidance of the Collection Management Librarian selects books, journals, and other media. Each academic department has a separate ("flat") budget for acquisition of technical/professional books and other publications, including journal subscriptions. This selection method keeps the Library collections closely linked to the needs of the faculty and students in individual departments. In addition, the Library participates in several Decision Driven Acquisitions (DDA) e-book programs. Rather than purchase books for just-in-case need, large lists of ebooks are made available through the library catalog to provide just-in-time access. Patrons discover the books, use them, and perhaps trigger a purchase if used or downloaded. The Library does not own all these titles outright but patrons still have access to them.

F. Overall Comments on Facilities

Safety is of paramount importance in the program. The department faculty works closely with our technical staff on safety issues to ensure a safe learning and research environment. Technical staff members are heavily involved in the preparation of the senior lab space each year and all graduate students receive safety training prior to working in the research or teaching laboratories. We also work closely with the Environmental Health and Safety Department at UMBC, who performs routine laboratory inspections and consult on all safety-related issues or questions.

CRITERION 8. INSTITUTIONAL SUPPORT

A. Leadership

Dr. Mark Marten, Professor and Chair, has leadership and management responsibility for the Department including the undergraduate and graduate programs. In particular, Dr. Marten is responsible for assigning and managing faculty workload including service and teaching responsibilities, organization of the Undergraduate and Graduate Committees and the recruitment, hiring and final oversight of part-time instructors. In partnership with the ABET Coordinator and Undergraduate Program Director, Dr. Marten is responsible for departmental assessment processes and the development of the ABET Self-Study. Dr. Marten serves as a member of the Undergraduate Program and Graduate Program Committees.

In addition to the leadership and management responsibilities above, Dr. Marten also has budgetary responsibility for the CBEE Department, represents the CBEE Department on the College Leadership Council and oversees the DBEE Departmental staff.

B. Program Budget and Financial Support

Process Used to Establish Budget and Institutional Support

The UMBC fiscal year begins on July 1. In December of each year, department chairs receive instructions from the Dean of COEIT pertaining to budget planning for the next fiscal year. These instructions include an overview of the budget process, a summary of the Dean's budget priorities, and information on budget scenarios that should be developed for each Department (which vary depending on the expectations for how the state budget is evolving). For example, a Chair might be asked to develop budget scenarios for a flat budget, 2% increase in the budget, and a 2% decrease in budget. In mid-January of each year, a College Budget Hearing is held with the Dean, the COEIT Director of Administrative Affairs, department chairs, center directors as appropriate, and an observer from UMBC's Division of Administration and Finance. Chairs are provided with a PowerPoint template that outlines the structure of the presentation, including data and analysis pertaining to the current fiscal year as well as budget predictions and requests for the upcoming fiscal year. Each Chair and Center Director presents their budget scenarios, and all those in attendance have the opportunity to ask questions and discuss potential issues. Following the COEIT Budget Hearing, the Dean compiles the information received and participates in a university-level budget hearing process in mid-spring. When the state legislative session concludes in early April, the university can determine which of the budget scenarios is appropriate, and further discussions are held at the university to level to prioritize budget cuts, new spending, and priority rebalancing. At the end of this budget process (usually in June), department chairs receive their final budgets for the coming fiscal year.

Because enrollments have been growing in most COEIT departments, the separate process by which UMBC monitors and responds to increasing enrollment is also of great importance to the department. Throughout the scheduling process leading up to a given semester, if enrollment projections indicate that additional course sections will need to be offered, the department may submit a request to the Provost's office to provide one-time "enrollment pressure" funding to be able to add that section. Typically this funding supports an adjunct instructor, and in some cases, if a strong enough case can be made, funding may be provided for a grader or TA as well. This process must be followed in each semester, but after two years of sustained enrollment pressure funding for a particular section, that funding "rolls to base" and is added to the department's permanent budget. While this process is helpful in addressing enrollment increases, the enrollment pressure funding often must be supplemented from other sources in order to hire full-time instructors with the base funding, because of the salary differential between adjunct instruction and full-time instructors. The Dean works closely with the departments and the Provost to ensure that the budget is adequate to meet these needs, and to use the regular budget cycle to add faculty as enrollments increase.

Financial support of departmental activities comes primarily from three sources: the state-supported budget, externally-funded grants and contracts, and student fees attached to laboratory classes. The state-supported budget process is described in the section above. Since 2007, a $50 student fee has been assessed on all laboratory courses to cover the cost of consumable supplies. In the CBEE Department, fees are collected for ENES 101 (every third semester when CBE is responsible for the course), ENCH 215, ENCH 225, ENCH 437L, ENCH 485L, and ENCH 486/686. Historically, the Department has not received financial support directly from alumni and all fundraising efforts were centralized at the university level.

Teaching Support

Teaching is well-supported at UMBC. The CBEE Department employs a combination of graduate teaching assistants (TAs) and undergraduate teaching fellows (TFs) to assist in teaching courses and grading student coursework. Teaching workshops are held routinely throughout the academic year and are open to all. The activities are coordinated through the Faculty Development Center as described above in the section on professional development. Enrollment pressure monies are available to departments with rapidly increasing enrollments to allow for additional support for TAs, graders and part-time faculty.

UMBC's Faculty Development Center offers a wide range of programs and services for supporting teaching and learning, including frequent workshops and book discussions, individual consultations and classroom observations, support for pedagogical innovation and research, learning assessment services, and support for faculty-led faculty learning communities (FLCs). The Hrabowski Innovation Fund grant program provides an opportunity for faculty to obtain financial support to introduce innovative teaching practices.

Within COEIT, the Dean's office runs a program for junior faculty that offers cross-departmental workshop sessions on a variety of topics related to teaching, research, and service. Recently offered topics have included managing large classes, addressing diversity in the classroom, and strategies for conflict resolution.

The Graduate School offers orientation and workshops for graduate teaching assistants, and has recently joined the Center for the Integration of Research, Teaching and Learning (CIRTL), a network of U.S. and Canadian universities with STEM graduate programs that are committed to improving the teaching skills and increasing the diversity of future STEM faculty members. Within this initiative, UMBC is creating learning communities for STEM graduate students to become effective teachers and learners, including focusing on real-world topics in classroom teaching, promoting inclusive learning, and encouraging teamwork and peer support through collaborative projects and study groups.

Individual departments determine what part of their budget will be allocated to instructional support (graders, teaching assistants, undergraduate teaching assistants (sometimes referred to as “teaching fellows”).

Resources for Acquisition, Maintenance and Upgrade of Infrastructures, Facilities and Equipment and Adequacy of Resources

Resources are currently sufficient to maintain and operate the facilities and equipment for the program. In particular, the equipment used in the teaching laboratories is adequate to support attainment of student learning outcomes. Furthermore, although some of this equipment is old, it is functional and well maintained. As mentioned earlier, $50/student is collected for the courses involving a significant laboratory experience in the department, and in the 2016-17 academic year this amounted to ~$7,000 in total. If the laboratory fees total is not spent in a given year, the funds are rolled over and used in subsequent years. This allows us to save for purchases of new equipment when necessary. In addition, the CBEE Department has committed up to an addition $10,000 to be spent each year for supplies, equipment repairs, and new equipment if needed (see also Section 7.D: Maintenance and Upgrading of Facilities).

Even though the facilities available in the current teaching laboratories are considered to be adequate, the faculty in the CBEE Department is committed to providing the highest possible educational experience for its students by the continuous improvement of these laboratories. Consequently, the CBEE Department will conduct a thorough review of the teaching laboratories during the 2017-18 academic year. The purpose of this review is to ensure that that the teaching laboratories reflect modern chemical engineering practice, meet student needs, and are consistent with the proposed revisions to the PEOs described earlier in this self-study. The end product of the review will be a laboratory plan to guide future modifications of the teaching laboratories. We anticipate this effort can be accomplishing within our current budget constraints. Nevertheless, we also intend to involve the CBEE Advisory Board and selected alumni in our discussions to provide input and to explore additional funding options as well as possible donations of equipment.

B. Staffing

The CBEE Department has one full-time Administrative Staff and two full-time Engineering Technicians. In addition, the Department hires undergraduate student workers to aid in routine office related activities. This level of staffing is sufficient to meet program needs.

In addition, the COEIT provides the services of the following personnel:

- James Milani, Director of Administration, for aid in developing and administering budgets
- Gina Fischer, Business Manager, for financial account management
- Kathy Suess, Specialist (Business Services Center), for financial account management
- Cathy Bielawski, Director Undergraduate Student Services, for recruiting and student advising
- Josh Abrams, Academic Advisor, for student advising
- Emily Abrams-Stephens, Academic Advisor, for student advising
- Anne Arey, Academic Advisor, for student advising
- Karen Mattingly, Coordinator of Special Projects, for data collection and analysis

Staff members receive training as needed or as requested. In some cases, such as when new software is rolled-out campus-wide, staff are required to attend training prior to using the new system. In other cases, staff members may request training through the Performance Management Process. In either situation, university staff with expertise in the appropriate area leads training. Training may occur through workshops or via online training programs. Two websites highlight upcoming/ongoing training opportunities from human resources: http://my.umbc.edu/groups/training/events, Technical training related to UMBC's Student Administration software is announced through the MyUMBC online system.

D. Faculty Hiring and Retention

Requests for the hiring of new faculty are made in May preceding the academic year of the search process. The chair makes requests to the Dean of the COEIT, who then transmits requests to the Provost. Decisions on whether to approve hiring are made prior to the beginning of the academic year. Once approved, a departmental search committee is convened and develops an advertisement and recruitment strategy as well as a diversity-hiring plan. All search committee members must participate in diversity awareness, which includes a focus on implicit bias and best practices for recruiting a diverse pool of candidates. These diversity-related activities are supported by UMBC's Strategies and Tactics for Recruiting to Improve Diversity and Excellence (STRIDE) Committee, which was formed to continue UMBC's longstanding commitment to inclusive diversity. The committee solicits, collects and screens applications and determines, with input from the entire faculty, which candidates to interview. On campus interviews are held in the spring semester after which all departmental faculty members participate in a voting procedure to determine which candidates will receive offers. The Department Chair then negotiates a start-up package with the faculty candidate and makes a recommendation for hiring to the Dean. The Dean then recommends the hire to the Provost, who gives final approval for all positions. Funds for start-up come from both the Provost and department funds. In 2015, the assistant professor start-up offer totaled $666,500 including $450,000 in equipment funds. Approximately 48% of the funds came from the Department with the remainder supported by the Provost.

Several faculty members have left the CBEE Department since the last ABET review. Drs. Enzer and Bayles left for other institutions. Dr. Good left to join the NSF and Dr. Ross became COEIT Dean. CBEE has hired Drs. Szeto, Lavik, and Raikar in the 2015-16 academic year and Drs. Das and Xu in the 2016-17 academic year. Tenure-track faculty members are provided emergency bridge funding from the Department when need to cover gaps in external support. In addition, the Department supports all professional development requests for both faculty and staff. While retention funds are available from the University, the Department has not had to request this mechanism of support in many years. In short, we have worked to establish a positive environment in which people can be successful and are supported in what they do.

E. Support of Faculty Professional Development

There is no line item in the CBEE budget specifically for professional development. However, as discussed in Section 6D, faculty professional development is valued at all levels and supported departmentally when requested. Since 2012, all requests for faculty professional development funds have been granted. In addition, since 2012 four faculty members have been approved for sabbatical leave as an investment in their continued development. Sabbatical leave is granted under the condition that the Department has the resources in place to cover the responsibilities of the faculty member. The Department Chair works with faculty members to plan for sabbatical leave to ensure continuity of all departmental functions. Therefore, the support for faculty professional development is very good.

For junior faculty, planning for professional development occurs through the creation and review of the Faculty Development Plans. For tenured faculty, individuals plan for their own development. These activities are supported through a variety of mechanisms including participation in grant activities, through allocation of funds from the departmental state-support budget and through sabbatical salary savings.

UMBC and COEIT provide a range of programs and services to support and retain current faculty. These include an orientation program for all new faculty, FDC support for teaching and learning (Section 8.B), COEIT programs for junior faculty (Section 8.B), new faculty luncheons throughout the year, and internal seed funding for research that is especially targeted at junior faculty.

PROGRAM CRITERIA

The relevant Program Criteria are as follows:

The program must demonstrate that graduates have: thorough grounding in the basic sciences including chemistry, physics, and biology appropriate to the objectives of the program; and sufficient knowledge in the application of these basic sciences to enable graduates to design, analyze, and control physical, chemical, and biological processes, consistent with the program educational objectives.

These Program Criteria are integrated into the CBEE Student Outcomes C1.1-C1.4 as shown below. These Student Outcomes represent the knowledge, skills and behaviors our students will have at the time of graduation that will enable them to achieve our Program Educational Objective C1 (Competency in the Discipline) within three to five years after graduation

Student Outcome C1.1: Students will be able to apply knowledge in mathematics and science.

Student Outcome C1.1 is directly related to the Program Criteria that graduates have a thorough grounding in the basic sciences including chemistry, physics, and biology appropriate to the objectives of the programs. As such, our graduates of our traditional track exceed the ABET minimum credit requirement for mathematics and science by 19 credit hours. This includes eight courses in chemistry (general, organic and physical with three laboratory courses, 25 credit hours), a two-course sequence in physics (8 credit hours) and one advanced science elective (3 credit hours). Graduates of our biotechnology and bioengineering track exceed the ABET minimum credit requirement for mathematics and science by 25 credit hours. This includes seven chemistry courses (general, organic, physical and biochemistry with one laboratory course, 23 credit hours), a two course sequence in physics (8 credit hours) and a three course sequence in biology (general, molecular and cellular, 11 credit hours). Graduates of our environmental and sustainability track exceed the ABET minimum requirement for mathematics and science by 13 credits hours. This includes seven chemistry courses (general, organic, and physical with one laboratory course, 19 credit hours) a two course sequence in physics (8 credit hours) and one advanced science elective (3 credit hours).

Student Outcome C1.2: Students will have proficiency in and be able to apply core chemical engineering principles.

Student Outcome C1.3: Students will be able to design a system, component, or processes using chemical engineering principles to meet desired needs within realistic constraints.

Student Outcome C1.4: Students will be able to use the techniques, skills and modern engineering tools (including computational, programming/modeling) necessary for the practice of chemical or biochemical engineering.

Student Outcomes C1.2-1.4 all contribute to the Program Criteria that graduates have sufficient knowledge in the application of these basic sciences to enable them to design, analyze, and control physical, chemical, and biological processes, consistent with the program educational objectives. The attainment of Student Outcome C1.2 ensures competence in core chemical engineering areas including thermodynamics, transport phenomena, reaction kinetics and reactor design, separation processes and process control through coursework in each of these areas. The attainment of Student Outcomes C1.3-1.4 ensures that graduates can use modern tools to design and analyze physical, chemical, and biological processes. Our two course capstone design, ENCH 444 and ENCH 446, specifically targets the Program Criteria related to process design and analysis.

Appendix A – Course Syllabi

1. ENCH 215: CHEMICAL ENGINEERING ANALYSIS

2. Credits and Contact Hours: 3 credits, 3 fifty-minute lectures per week and 1 two-hour discussion session per week.

3. Instructor: Jennie Leach

4. Textbook:

Felder, R.M., Rousseau, R.W., and Bullard, L., Elementary Principles of Chemical Processes, 4th ed., New York: Wiley and Sons, 2016.

5. Specific Course Information:

a. Course Catalog Description: Introduction to methods of chemical engineering calculations and analysis. Stoichiometric relations; material and energy balances; and behavior of gases, vapors, liquids and solids. Analytical and computer methods are presented.

b. Prerequisites: ENES 101, CHEM 102

c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

By the end of the course, the student should be able to work with the following:

- **Basic engineering calculations.** Convert quantities from one set of units to another quickly and accurately; define, calculate and estimate properties of process materials including fluid density, flow rate, chemical compositions variables, fluid pressure and temperature.

- **Material and energy balance calculations.** Draw and label process flowcharts from verbal process descriptions; carry out degree-of-freedom analyses; write and solve material and energy balance equations for single-unit and multiple-unit processes, processes with recycle and bypass and reactive processes.

- **Applied physical chemistry.** Perform pressure-volume-temperature calculations for multi-component or multi-phase systems. Calculate internal energy and enthalpy changes for fluids undergoing changes in pressure, temperature, phase and chemical composition. Incorporate the results of these calculations into process material and energy balance calculations.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences*
C1.2: Demonstrate proficiency in chemical engineering principles*
C1.3: Design processes
C1.4: Use modern tools*
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs
C4.1: Communicate in writing
C5.1: Define problems
C5.2: Locate information*
C5.3: Assimilate information
C5.4: Self-assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Basic chemical engineering calculations
- Processes and process variables
- Fundamentals of material balances (non-reactive and reactive systems)
- Single-phase systems
- Multiple-phase systems
- Material and energy balances
- Balances on non-reactive processes
- Balances on reactive processes

1. ENCH 225L: CHEMICAL ENGINEERING PROBLEM SOLVING AND EXPERIMENTAL DESIGN LAB

2. Credits and Contact Hours: 4 credits, three 50-minute lectures per week and a 110-minute lab per week

3. Instructor: Neha B. Raikar

4. Textbook:

Jeter and Donnell, *Writing Style and Standards in Undergraduate Reports*, 2nd or 3rd edition, College Publishing

5. Specific Course Information:

a. Course Catalog Description: Introduction to the scientific method as applied to chemical engineering processes associated with thermodynamics and fluid, heat and mass transport. Computational and experimental tools are introduced. Students will formulate hypotheses to test physical phenomena associated with chemical engineering processes, design experiments based on their hypotheses, perform experiments, and use appropriate computational and programming tools as well as statistical methods to analyze their data and its significance. Issues of safety and ethics, as applied to chemical engineering, also will be discussed.

b. Prerequisites: ENCH 215: Chemical Engineering Analysis and ENGL 100: Composition with a "C" or better

c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students develop skills to formulate and solve problems in chemical engineering
- Students learn to apply statistical concepts like mean, variance, confidence intervals, hypothesis testing etc. to experiments
- Students can use computing tools like MATLAB and Excel to analyze data and construct models
- Students design and conduct experiments, collect useful data, critically analyze and report results.

- Students develop skills to be able to work in groups, demonstrate leadership and handle conflicts in group setting

- Students formulate responsible and ethical responses in personal and professional settings

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.4: Use modern tools*
C1.5: Understand Broader Impact*
C2.1: Solve open-ended problems*
C2.3: Design and conduct experiments*
C2.4: Analyze and interpret data*
C3.1: Work in Teams*
C3.2: Fill Various Roles*
C3.3: Resolve Conflict*
C4.1: Written Communication*
C5.1: Define Problems*
C5.4: Self-Assessment*

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Degrees of Freedom Analysis
- Descriptive Statistics
- Probability Distributions
- Single and multiple sample hypothesis testing
- Confidence Intervals on the mean and variance
- Analysis of Variance
- Correlation and Linear Regression
- Ordinary Differential Equations
- Numerical Integration
- Ethical issues
- Introduction to Process Safety

1. ENCH 300: CHEMICAL PROCESS THERMODYNAMICS

2. Credits and Contact Hours: 3 credits, 3 fifty-minute lectures per week and 1 two-hour discussion session per week.

3. Instructor: Mariajose Castellanos

4. Textbook:

Dahm K.D. and Visco, D. P. 1st ed., Fundamentals of Chemical Engineering Thermodynamics,: CL Engineering, 2014.

5. Specific Course Information:

a. Course Catalog Description: Principles of thermodynamics and their application to engineering problems. First and second laws of thermodynamics; properties of gases; liquids and solids; phase equilibrium; flow and non-flow systems; energy conversion; production of work from heat; thermodynamic analysis of processes; equilibrium-stage operations and the thermodynamics of chemically reacting systems.

b. Prerequisites: ENCH215, MATH 251, CHEM 351

c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

By the end of the course, the student should be able to work with the following:

- Students define and derive basic thermodynamic properties.
- Students use thermodynamic principles to solve steady state and transient problems concerning changes in properties of pure fluids.
- Students identify which laws of thermodynamics are important to describe the behavior of different systems.
- Students are able to describe the working parts and actions of a heat engine and evaluate heat absorbed and heat rejected in a carnot engine or refrigerator
- Students are able to calculate the change of entropy for a process
- Students compare ideal and real work and design alternative to improve the process
- Students are able to outline mass and energy balances for unit operations and calculate heat and work for unit operations (Identifying all appropriate assumptions)
- Students solve the different types of cycles used in the production of power
- Students describe thermodynamic principles governing phase equilibrium and are able to use phase diagrams for vapor/liquid mixtures, calculate phase composition, and estimate phase behavior for complex (ideal and real) mixtures.

- Students describe and use thermodynamic principles to estimate equilibrium compositions for reacting chemical mixtures.
- Students discuss contemporary issues in thermodynamics, and how the chemical engineering practice impacts society.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles*
C1.3: Design processes*
C1.4: Use modern tools
C1.5: Understand Broader Impact
C2.1: Solve open-ended problems*
C2.2: Evaluate solutions/designs*
C4.1: Communicate in writing
C5.1: Define problems
C5.2: Locate information
C5.3: Assimilate information
C5.4: Self-assessment*

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- 1st law
- Equilibrium/Reversibility
- Enthalpy & Heat Capacity
- Equations of Sate (ideal, virial, van der Waals, Cubic Equations of State)
- Heat Effects
- Second Law, Temperature Scale, Entropy
- Third law
- Flow Processes, Power from Heat, Refrigeration
- Properties of Fluids
- Residual properties
- Phase Equilibrium
- Solution Theory, Fugacity
- Chemical Reaction Equilibrium

1. ENCH 310: ENVIRONMENTAL CHEMISTRY AND BIOLOGY

2. Credits and Contact Hours: 3 credits, two 75-minute lectures per week

3. Instructor: Lee Blaney

4. Textbook:

Benjamin, M.M., *Water Chemistry,* 2nd ed., Illinois: Waveland Press, 2015.

5. Specific Course Information:

a. Course Catalog Description: Aqueous chemistry. Acids and bases. Titrations and buffers. Dissolved gases. Metal-ligand complexes. Precipitation chemistry. Redox chemistry. Chemical equilibrium modeling.

b. Prerequisites: CHEM 351: Organic Chemistry I. MATH 225: Introduction to Differential Equations

c. Designation: Required course (environmental engineering and sustainability track).

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students develop a theoretical framework for determining the inorganic chemical composition of natural waters using reactions that relate to acid-base, dissolved gas, complexation, precipitation, and redox chemistry.

- Students can apply fundamental chemical principles to understanding the fate of environmentally-relevant species (*e.g.*, chromium, arsenic, phosphorus, and lead, among others) in natural or engineered systems, such as drinking water and wastewater treatment plants.

- Students can generate log C-pH, log C-pe, and pe-pH diagrams by hand and in Excel, and they can use these diagrams to describe the complex composition of aqueous, gaseous, and solid chemicals in water systems for different pH, redox, and temperature conditions.

- Students can employ an advanced chemical equilibrium modeling software platform (*i.e.*, MINEQL+) to solve comprehensive water chemistry problems.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a Foundation in Math/Sciences
C1.2: Demonstrate Proficiency in Chemical Engineering Principles
C1.4: Use Modern Tools
C1.5: Understand Broader Impact
C2.1: Solve Open-Ended Problems
C2.4: Analyze Data
C3.1: Work Effectively in Teams
C4.1: Communicate in Writing
C5.1: Define Problems
C5.2: Locate Information

7. Topics Covered:

- Basics of aquatic chemistry
- Chemical reactivity, reactions, and equilibrium
- Effect of temperature on equilibrium constant
- Entropy and Gibbs energy
- Chemical potential as the driving force for chemical reactions
- Acid-base speciation and log C-pH diagrams
- Effects of nonideal solute behavior
- The TOTH equation and the proton condition
- Chemical titrations and alkalinity
- Derivation of buffer intensity
- Henry's Law and gas-liquid equilibrium
- CO_2 dissolution, alkalinity, and acidity
- Chemistry of metals in aqueous systems
- Formation and structure of metal complexes
- log C-pH diagrams for dissolved metals
- Mixed ligand complexes and chelating agents
- Predominance area diagrams (with and without solids)
- Precipitation and dissolution chemistry
- The solubility product
- Determination of oxidation numbers
- Balancing redox reactions
- Redox speciation and log C-pe diagrams
- pe-pH predominance area diagrams
- Use of MINEQL+ chemical equilibrium modeling software

1. ENCH 412: Environmental Physicochemical Processes

2. Credits and Contact Hours: 3 credits, two 75-minute lectures per week

3. Instructor: Christopher J. Hennigan

4. Textbook:

Benjamin, M. M., Lawler, D. F., *Water Quality Engineering: Physical/Chemical Treatment Processes*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2013.

5. Specific Course Information:

a. Course Catalog Description: This course focuses on physicochemical processes that control the fate of contaminants in engineered and natural systems is discussed. Physicochemical phenomenon is first introduced from a phenomenal standpoint, then its role in both engineered and natural systems discussed. At the end of the course, the student will be able to understand the basic physicochemical phenomena that control the fate of pollutants in the environment.

b. Prerequisites: ENCH 310: Environmental Chemistry and Biology

c. Designation: Elective.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students understand each unit operation and its role in the overall drinking water treatment process.

- Students can apply mathematical and chemical principles to reactors and reaction kinetics involved with drinking water treatment processes.

- Students can apply mathematical and chemical fundamentals to quantitatively characterize the following drinking water treatment processes: coagulation, flocculation, sedimentation, granular filtration, aeration, air stripping, adsorption, disinfection, oxidation and advanced oxidation, membrane filtration, and reverse osmosis.

- Students can predict the effects of changing water quality and engineering parameters on the treatment efficacy of each step in the drinking water treatment process.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes
C1.5: Understand Broader Impact
C2.2: Evaluate solutions/designs
C5.1: Define problems
C5.2: Locate information

7. Topics Covered:

- Chemical and biological pollutants in water
- Ideal and non-ideal reactor hydraulics
- Coagulation
- Flocculation
- Sedimentation
- Granular filtration
- Aeration and Air stripping
- Adsorption
- Ion exchange
- Water softening
- Disinfection
- Disinfection byproduct formation and control
- Membrane filtration
- Reverse osmosis
- Oxidation and advanced oxidation

1. ENCH 425: TRANSPORT I: FLUIDS

2. Credits and Contact Hours: 3 credits, three 50-minute lectures per week

3. Instructor: Neha B. Raikar

4. Textbook:

Philip J. Pritchard, *Introduction to Fluid Mechanics*, Fox and McDonald's, 8th /9th Edition

5. Specific Course Information:

a. Course Catalog Description: Fluid properties, fluid statics, flow concepts and basic equations, and viscous effects. Applications in measurements of flow. Design of fluid flow equipment.
b. Prerequisites: ENCH 215: Chemical Engineering Analysis and MATH 225: Introduction to Differential Equations with a "C" or better
c. Designation: Required course.

6. Specific Goals for the Course:

b. Specific Outcomes of Instruction:

- Students are familiar and are able to apply the basic concepts conservation of mass, energy, and momentum
- Students can formulate and solve problems in rheology, fluid statics and dynamics
- Students can use computing tools like MATLAB and Excel to solve fluid flow problems
- Students understand how to design experiments through dimensional analysis

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences*
C1.2: Demonstrate proficiency in chemical engineering principles*
C1.4: Use modern tools
C2.1: Solve open-ended problems*
C2.3: Design and conduct experiments*
C2.4 Analyze and interpret data
C5.2 Locate information

C5.3 Assimilate information
C5.4 Self-assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Flow Classification
- Rheology
- Fluid Statics
- Conservation of Mass
- Conservation of Momentum
- Conservation of Energy
- Continuity and Navier-Stokes
- Introduction to Computational Fluid Dynamics
- Kinematics
- Stream function and Potential function
- Inviscid flows and Bernoulli's equation
- Turbulence
- Pipe flow
- Dimensional Analysis and Dynamic Similarity
- Pumps
- External flows and Drag force

1. ENCH 437L: Chemical Engineering Laboratory

2. Credits and Contact Hours: 3 credits, one 50-minutes lecture and one 4.25 hours laboratory per week

3. Instructors: Gautom Das
Brian Reed

4. Textbook:

- Jeter, S. and Donnell, J. *Writing Style and Standards in Undergraduate Reports*. 3^{rd} ed., Virginia: College Publishing, 2016.

5. Specific Course Information:

a. Course Catalog Description: Application of chemical engineering process and unit operations principles in small-scale semi-commercial equipment. Data from experimental observations are used to evaluate performance and efficiency of operations. Significant emphasis has been on correct presentation of results in report form.

b. Prerequisites: ENCH 427: Heat and mass transfer
ENCH 440: Chemical engineering kinetics

c. Designation: Required course (Traditional Track)

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students use the knowledge acquired in previous mathematics, science and chemical engineering courses to analyze and interpret information acquired by operating process equipment.
- Students work as teams to conduct and design experiments. The course□is expected to enhance their ability to use the techniques, skills and tools necessary to design experiments and validate the theoretical models.
- Students acquire and analyze data as groups, which should enhance interpersonal skills. Students learn software such as MS excel, Matlab and other computer tools for analysis and interpretation of the data.
- Students learn safety and environmental concerns related to engineering operations.

- Students communicate technical information to others through written reports.

- **Writing in the Discipline: ENCH 437L is designated as writing intensive (WI)**. Formal laboratory reports constitute the writing component of this course. Laboratory reports require critically present appropriate technical background material, present data in a clear and logical way, concisely interpret results and discuss the implications of data. Academic integrity with respect to writing has been discussed through out the semester. Topics include plagiarism, citation of references, falsification of data and misrepresentation of results. All laboratory reports have been evaluated for both writing and technical content.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes
C1.4: Use modern tools*
C1.5: Broader impact*
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs
C2.3: Design experiments*
C2.4: Analyze data*
C3.1: Work effectively in teams*
C3.2: Fill various roles*
C3.3: Resolve conflicts*
C4.1: Communicate in writing*
C5.1: Define problems
C5.2: Locate information
C5.3: Assimilate information
C5.4: Self-assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Absorption experiment (using computer simulation).
- Unsteady state heat transfer.
- PID control of a double pipe heat exchanger.
- Fixed and fluidized beds

1. ENCH 440: CHEMICAL ENGINEERING KINETICS

2. Credits and Contact Hours: 3 credits, two 75-minute lectures and one 50-minute problem session per week.

3. Instructor: Mark R. Marten

4. Textbook:

Fogler, HS, *Essentials of Chemical Reaction Engineering*, Pearson Education, Inc., NJ, 2011.

5. Specific Course Information:

a. **Course Catalog Description:** Fundamentals of chemical reaction kinetics and their application to the design and operation of chemical reactors. Reaction rate theory, homogeneous reactions in batch and flow systems, heterogeneous reactions and catalysis, and biochemical reactions. Catalytic reactor design.

b. **Prerequisites:** ENCH 300 Chemical Process Thermodynamics, ENCH425 Transport I: Fluids, and CHEM 301 Physical Chemistry 1 with a "C" or better. CHEM 303 Physical Chemistry for the Biochemical Sciences can be taken concurrently.

c. **Designation:** Required course.

6. Specific Goals for the Course:

a. **Specific Outcomes of Instruction:**

- Students design and analyze isothermal and non-isothermal reactors, simultaneously performing mass and energy balances as needed. They do this for reactors with single or multiple chemical reactions taking place.

- Students are able to size batch, semi-batch and continuous reactors operated both isothermally and non-isothermally for both gas-phase and liquid-phase situations. They are able to both develop analytical solutions and to use numerical tools when required.

- Students analyze reaction-rate data to deduce reaction mechanisms and derive reaction rate laws. They then use these data to fit proposed rate laws to determine rate-law parameters.

- Students understand basic principles related to catalytic reactions and reactors and are able to design reactors for both single and multiphase systems. They utilize Polymath, MATLAB and Excel as tools to assist in design, modeling and interpretation of data.

b. Student Outcomes Addressed by the Course:

C1.1 Have a foundation in math/sciences *
C1.2 Demonstrate proficiency in chemical engineering principles *
C1.3 Design processes *
C1.4 Use modern tools
C1.5 Ethics and Safety
C2.1 Solve open-ended problems
C2.2 Evaluate solutions/designs
C2.3 Design experiments
C2.4 Analyze and interpret data *
C5.2 Locate information
C5.3 Assimilate information
C5.4 Self-assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Shear Stress and Rheology
- Fluid Statics
- Conservation of Mass
- Conservation of Momentum
- Conservation of Energy
- Continuity and Navier-Stokes Equations
- Introduction to Computational Fluid Dynamics
- Kinematics
- Stream function and potential function
- Dimensional Analysis and Dynamic Similarity
- Turbulence
- Pipe flow
- Centrifugal Pumps
- External flows and Drag force

1. ENCH 442: CHEMICAL ENGINEERING SYSTEMS ANALYSIS

2. Credits and Contact Hours: 3 credits, three 50-minute lectures per week

3. Instructor: Neha B. Raikar

4. Textbook:

Crowl and Louvar, *Chemical Process Safety: Fundamentals with Applications*, 3rd edition, 2011.

5. Specific Course Information:

a. Course Catalog Description: Dynamic response of process systems. Analysis, optimization, and design of simple control systems, closed-loop response, and dynamic testing. Design and simulation of systems for chemical process safety.
b. Prerequisites: ENCH 225L: Chemical Engineering Problem Solving and Experimental Design Lab, ENCH 425: Transport I -Fluids, ENCH 300: Chemical Process Thermodynamics, and MATH 225: Introduction to Differential Equations with a "C" or better
c. Designation: Required course.

6. Specific Goals for the Course:

c. Specific Outcomes of Instruction:

- Students understand the importance of system dynamics and feedback control in Chemical Engineering.
- Students are able to develop fundamental and empirical models with time dependence.
- Students are able to analytically solve linear dynamic models and to use computer - based tools for dynamic model simulation.
- Students develop literacy with piping and instrumentation diagrams and basic control systems
- Students conduct Hazards and Operability (HAZOP) Studies on chemical processes

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences*
C1.2: Demonstrate proficiency in chemical engineering principles
C1.4: Use modern tools*
C1.5: Understand Broader Impact*
C2.1: Solve open-ended problems*
C2.2: Evaluate/design solutions*
C2.4: Analyze and interpret data
C3.1: Work in Teams
C4.1: Written Communication
C5.1: Define Problems*
C5.4: Self-Assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Process Optimization
- Process Control
- Develop mathematical models of processes
- Feedback and feedforward control
- Types of process diagrams
- Tuning and Troubleshooting
- Process Safety and application
- Toxicology and Industrial Hygiene
- Toxic Release, Source and Dispersion Models
- Fires and Explosions
- Introduction to Reliefs and Sizing
- Hazard Identification and Risk Assessments

1. ENCH 444: PROCESS ENGINEERING ECONOMICS AND DESIGN

2. Credits and Contact Hours: 3 credits, three 50-minute lectures per week

3. Instructor: Gautom Das

4. Textbook:

Turton, R.; Bailie, R. C.; Whiting, W. B.; Shaeiwitz, J. A. and Bhattacharyya, D. *Analysis, Synthesis and Design of Chemical Processes*, 4th Ed., New Jersey: Prentice Hall, 2012.

Peters, M.S.; Timmerhaus, K. D.; and West, R. E. *Plant Design and Economics for Chemical Engineers, 5th Ed.*, New York: McGraw-Hill, 2003.

5. Specific Course Information:

a. Course Catalog Description: Principles of chemical engineering economics and process design. Emphasis on equipment types, equipment design principles, capital cost estimation, operating costs and profitability.

b. Prerequisites:	ENCH 427: Heat and Mass Transfer
	ENCH 440: Chemical Engineering Kinetics
Corequisite:	ENCH 445: Separation Processes

c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students will have a more in-depth understanding of the basic concepts underlying the design and operation of a chemical process to produce a chemical of interest.
- Students can perform quantitative calculations related to the design process to meet desired needs within realistic constraints such as economic, environmental, social, health and safety, and sustainability.
- The students will work in small teams to demonstrate their fundamental engineering knowledge, research capabilities and resourcefulness while developing a preliminary design project.
- Students can use a chemical process simulator such as Aspen Plus to design a process of interest, and numerically solve systems of equations and constrains using appropriate software such as Excel or Matlab.
- Students will also understand the professional and ethical responsibilities as engineers.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes*
C1.4: Use modern tools
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs*
C4.1: Communicate in writing*
C5.1: Define problems*
C5.2: Locate information
C5.3: Assimilate information
C5.4: Self-assessment*

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- General Design Considerations
- Process Design Development
- The Structure and Synthesis of Process Flow Diagram
- Flowsheet Synthesis & Development
- Interest, Time Value of Money, Taxes, and Fixed Charges
- Analysis of Cost Estimation
- Profitability, Alternative Investments, and Replacements
- Software Used in Process Design: Aspen Plus
- Material Transfer Equipment – Design & Costs
- Reactor, Heat Transfer, Separation Equipment – Design & Costs
- Heat Integration
- Materials of Construction
- Ethics and Professionalism
- Health, Safety and Environment

1. ENCH 445: SEPARATION PROCESSES

2. Credits and Contact Hours: 3 credits, two 75-minute lectures per week

3. Instructor: Douglas D. Frey

4. Textbook:

Wankat, P. C., *Separation Process Engineering*, 4^{th} ed., New York: Prentice Hall, 2016.

5. Specific Course Information:

a. Course Catalog Description: Solution thermodynamics. Phase equilibrium. Characteristics of separation processes. Simple and multistage equilibrium processes. Design and operation of binary and multicomponent separation processes. Computational approaches.
b. Prerequisites: ENCH 427: Heat and mass transfer
c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students are familiar with the basic concepts underlying the design and operation of single-stage equilibrium processes, distillation columns having binary or multicomponent feeds, solvent extraction processes, strippers, absorbers, and membrane processes.

- Students can perform quantitative calculations related to the design and operation of single-stage equilibrium processes, distillation columns having binary or multicomponent feeds, solvent extraction processes, strippers, absorbers, and membrane processes.

- Students can use a chemical process simulator such as COCO or Aspen to solve problems related to separation processes, and can set up and numerically solve systems of algebraic equations and constrained optimization problems related to separation processes using appropriate software such as Excel or Matlab.

- Students understand how knowledge of the physical properties of the substances to be separated can be used as a guide for selecting an appropriate separation process.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences*
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes*
C1.4: Use modern tools*
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs
C4.1: Communicate in writing
C5.1: Define problems
C5.2: Locate information
C5.3: Assimilate information*
C5.4: Self-assessment

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- General features of separation processes.
- Numerical methods for systems of algebraic equations
- Numerical methods for constrained optimization problems
- Thermodynamics of phase equilibria.
- Binary and multicomponent single-stage processes.
- Lever rule and description rule
- Rate-governed processes
- Staging of separation processes.
- Use of COCO and Aspen for chemical process simulation
- Binary and multicomponent distillation
- Absorption, stripping, and extraction
- Kremser-Sauders-Brown equation.
- Equipment capacity
- Continuous contactors
- Membrane processes
- Selection of separation processes

1. ENCH 446: PROCESS ENGINEERING ECONOMICS AND DESIGN II

2. Credits and Contact Hours: 4 credits, 3 fifty-minute lectures per week and 1 two-hour discussion session per week.

3. Instructor: Mariajose Castellanos

4. Textbook:

None

5. Specific Course Information:

- **a. Course Catalog Description:** Application of chemical engineering principles for the design of chemical processing equipment. Typical problems in the design of chemical plants. Comprehensive reports are required.
- **b. Prerequisites:** ENCH 444, ENCH 445, ENCH 442 (maybe taken co-currently)
- **c. Designation:** Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- By the end of the course, the student should be able to work with the following:
- Student will be able to build upon the foundation of the chemical engineering foundational courses and concepts introduced in previous courses and focuses on an actual design project.
- Students will develop a more in-depth appreciation of the skills required for working in a design setting.
- Students will prepare informal and formal presentations on their progress and prepare written comprehensive design reports.
- Students will utilize concepts associated with financial analysis and sustainability while demonstrating working knowledge of these principles and how they balance with design choices.
- Students develop skills associated with working in a group, practice leadership in a group setting, and learn tools to resolve (or avoid) conflicts when working in a group.
- Students become proficient on a Chemical Process Simulator.

- Students should be able to formulate ethical responses in personal and professional settings.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes*
C1.4: Use modern tools*
C1.5: Understand Broader Impact*
C2.1: Solve open-ended problems*
C2.2: Evaluate solutions/designs*
C2.4: Analyze Data
C3.1: Work effectively in teams*
C3.2: Fill Various Roles*
C3.3: Resolve Conflict*
C4.1: Communicate in writing
C4.2: Communicate orally*
C5.1: Define problems*
C5.2: Locate information*
C5.3: Assimilate information*
C5.4: Self-assessment*

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

1. Material and Energy Balance
2. Materials of Construction / Fabrication Methods
3. Material Transfer Equipment – Design & Costs
4. Reactor Equipment – Design & Costs
5. Heat Transfer Equipment – Design & Costs
6. Separation Equipment – Design & Costs
7. Heat Integration – Design & Costs
8. Process Control – Design & Costs
9. Simulation and Optimization of processes
10. 0% emission and sustainability
11. Working with people as individuals and teams and Strength Quest
12. Oral communication in different settings

1. ENCH 474: AIR POLLUTION

2. Credits and Contact Hours: 3 credits, two 75-minute lectures per week

3. Instructor: Christopher J. Hennigan

4. Textbook:

Cooper, C. D., and Alley, F. C., *Air Pollution Control* (4th Ed), Waveland Press, Long Grove, IL, 2011.

5. Specific Course Information:

a. Course Catalog Description: The objective of this course will be to provide an introduction to the sources, chemistry and fate of airborne pollutants. In general, it will be broken into three parts: sources and dispersion processes, gas-phase chemistry and particulate-phase chemistry. The focus will be on the urban atmosphere, but as some pollutants have impacts well beyond their source region some discussion of global cycles will be appropriate. The course should provide a general introduction to atmospheric chemistry including both gas-phase and particulate-phase processes.

b. Prerequisites: ENCH 427: Transport Processes II: Mass Transfer ***and*** ENCH 440: Chemical Engineering Kinetics
c. Designation: Elective.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students understand the major sources of air pollution, how pollutants are transported and transformed in the atmosphere, and their environmental effects.

- Students can describe different air pollution control technologies and how the chemical and physical properties of the pollutant can be used to select the optimum control technology for a given process.

- Students can apply fundamentals of chemical engineering to qualitatively and quantitatively characterize the formation and control of air pollutants.

- Students can perform quantitative calculations related to air pollution formation and emissions from a variety of combustion processes.

- Students can perform quantitative calculations to the design of air pollution control systems to meet current regulatory standards for criteria air pollutants.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.1: Have a foundation in math/sciences
C1.2: Demonstrate proficiency in chemical engineering principles
C1.3: Design processes
C1.5: Understand Broader Impact
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs
C5.1: Define problems
C5.2: Locate information

7. Topics Covered:

- Atmospheric pollutants and regulations
- Atmospheric structure and meteorology
- Energy fundamentals – combustion and efficiency
- Chemical fundamentals – radical reactions, Henry's law, K_{sp}
- Oxides of sulfur – sources and chemistry
- Oxides of sulfur – control technology and design
- Stratospheric ozone chemistry
- Tropospheric ozone chemistry
- Nitrogen oxides – sources and chemistry
- Nitrogen oxides – control technology for stationary sources
- VOCs – sources and chemistry
- VOCs – control technology for stationary sources
- Control of motor vehicle emissions
- Particulate matter – sources and effects
- Particulate matter control: gravitational settlers
- Particulate matter control: cyclones
- Particulate matter control: filtration
- Particulate matter control: electrostatic precipitators
- Global climate change

1. **ENCH 482 – Biochemical Engineering**

2. **Credits and contact hours:** 3 credits – Two seventy five minute lectures per week

3. **Instructor:** Peng Xu

4. **Textbook:**
   Bioprocess Engineering, Basic Concepts, 2nd Edition, Michael L. Shuler and Fikret Kargi, Prentice Hall, 2001.
   Essential Cell Biology, 3rd Edition, Alberts, et al. Eds., Garland Science, New York, 2009.
   Other supplemental materials: Biochemical Engineering, 2nd Edition, Douglas S. Clark, Harvey W. Blanch, Chemical Industries, 1995.

5. **Specific Course Information:**
   a. **Course Catalog Description:** Introduction to biochemical, microbiological and physical phenomena relevant in the bioprocess industry: basic biochemistry, enzyme and cell growth kinetics, modern biological techniques (e.g., DNA sequencing, microarray analysis, proteomics) and topics related to industrial fermentation (e.g., operating modes, mixing, mass transfer, scale-up).
   b. **Prerequisite:** ENCH 427 and ENCH 440
   c. **Designation:** Required Course for Biotrack and Elective for Traditional track

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction:**
   - Understand and discuss basic biological principles and techniques in molecular biology relevant to biochemical engineering and production of microbially derived products.
   - Solve problems, analyze data and draw conclusions regarding problems or data involved in enzyme kinetics.
   - Understand how batch, fed-batch and continuous flow bioreactors operate and be able to analyze data from these types of bioreactors.
   - Understand how principles of transport (heat, mass, momentum) and microbial kinetics are relevant in the design of bioreactors.
   - Understand how to read and summarize salient features of a technical journal article in the biochemical engineering literature.

Course Learning Outcomes:
- A comprehensive understanding of how biological principles and molecular genetics could be used to advance modern biochemical engineering in terms of production of microbially derived products ranging from primary metabolites (ethanol, amino acids, organic acids) to secondary metabolites (antibiotics) and protein drugs (vaccines). Introduction of the concept of Metabolic engineering and

Synthetic biology that allow student to explore further.

- Quantitative skills to solve/derive basic enzyme kinetic equations based on pseudo-steady state hypothesis. Be able to experimentally determine critical enzyme kinetic parameters.
- A quantitative perspective how batch, fed-batch and continuous flow bioreactors will operate and which type of bioreactor is suitable for a specific metabolite. Understand which operation mode works best for specific type of fermentation. Be able to solve mass balance equation under stable CSTR conditions or perfusion conditions.
- Application of principles of transport (heat, mass, momentum) and microbial kinetics to improve oxygen transfer and bioreactor scale-up.
- Be able to use computational software like Matlab or Python to model and simulate cell growth, substrate consumption, production formation under different operating conditions.

b. Student Outcomes Addressed by the Course:

C1.1 Students will be able to apply knowledge in mathematics and science.
C1.2 Students will have proficiency in and be able to apply core chemical engineering principles.
C1.4 Students will be able to use the techniques, skills and modern engineering tools (including computational, programming/modeling) necessary for the practice of chemical or biochemical engineering.
C1.5 Students will have an elementary knowledge of the contemporary issues including an understanding of professional and ethical responsibility, sustainability, health & safety and the impact of engineering solutions in a global, economic, environmental and societal context.
C2.1 Students will be able to analyze/solve open ended problems in chemical engineering.
C2.4 Students will be able to analyze and interpret data in order to solve engineering problems. C4.1 Students will be able to communicate effectively in written form.
C4.2 Students will be able to communicate effectively in oral form.
C5.2 Students will have the ability to locate tools and information relevant to a problem. C5.3 Students will have the ability to assimilate information relevant to a problem.
C5.4 Students will be able to assess their own ability/knowledge to solve a problem and know when to seek help.

7. Brief list of topics to be covered: (Chapters correspond to Text #1 above):

Biochemical and Bioprocess Engineering (Ch 1)
Basic Biology and Biochemistry of Cells (Ch 2)
Enzyme Kinetics and Immobilization (Ch 3)
Genetics & Cellular Control Systems (Ch 4)
Metabolism (Ch 5)
Cell Growth Kinetics (Ch 6)
Stoichiometry (Ch 7)

Genetic Engineering (Ch 8, 14)
Bioreactor Operation (Ch 9)
Bioreactor Selection, Scale-up, Operation, and Control (Ch 10)

1. ENCH 485L: Biochemical Engineering Lab

2. Credits and Contact Hours: 4 credits, one 50 minute lecture and two 230-minute labs per week

3. Instructor: Erin Lavik

4. Textbook:

K. Barker. *At the Bench: A Laboratory Navigator*. (any edition) New York, NY: Cold Spring Harbor Press.

5. Specific Course Information:

a. Course Catalog Description: Conduct experiments to study microbial growth and product formation kinetics. Study enzyme kinetics. Conduct protein isolation, purification and concentration experiments. Analyze experimental data and prepare written reports and oral presentations. Observe laboratory safety precautions. This course is designed to teach modern chemical and biochemical laboratory practice. Students will learn aspects of heat and mass transfer of relevance to the bioprocess industry. In addition, they will learn aspects of microbial growth and product formation kinetics. Simple cloning techniques and enzyme/antibody assays will be introduced. Students will isolate and purify proteins.
b. Prerequisites: ENCH 427: Heat and mass transfer
c. Designation: Required course.

6. Specific Goals for the Course:

a. Specific Outcomes of Instruction:

- Students will be able to use the knowledge acquired in previous mathematics, science and chemical engineering courses to analyze and interpret information acquired by operating process equipment or carrying out biochemical engineering experiments.
- Students will be able to communicate technical information to others through written reports.
- Students will enhance their ability to conduct and design experiments, including consideration of safety concerns.
- Students will gain experience with working as part of a team.
- Students will increase their ability to use the techniques, skills and tools necessary for engineering practice.

6. Specific Goals for the Course (cont.):

b. Student Outcomes Addressed by the Course:

C1.3: Design processes
C1.4: Use Modern Tools*
C1.5: Broader Impacts*
C2.1: Solve open-ended problems
C2.2: Evaluate solutions/designs
C2.3: Design and Conduct Experiments*
C2.4: Analyze Data*
C3.1: Work Effectively in Teams*
C3.2: Fill Various Roles*
C3.3: Resolve Conflicts*
C4.1 Communicate in Writing*
C5.1: Define problems
C5.2: Locate information
C5.3: Assimilate information

*Outcome is part of the direct assessment activity of the department.

7. Topics Covered:

- Basic biochemical assays
- Data analysis
- Statistics
- Scientific writing
- Presentation skills
- Enzyme lab
- Appropriateness of assays under different conditions
- Sensitivity versus specificity
- Compartment models to connect in vitro models to likely in vivo outcomes
- Bacterial culture

1. BIOL 141 – FOUNDATIONS OF BIOLOGY: CELLS, ENERGY AND ORGANISMS

2. **Credits and Contact Hours:** 4 Credits, 2.5 hours/week lecture, 1 hour/week discussion

3. **Instructor:** Dr. Elizabeth Feeser

4. **Required Text Book and Other Supplemental Material**

   Biological Science, by Freeman, Quillin and Allison, 6th Edition

5. **Specific Course Information:**
   a. **Course Catalog Description:** This course for majors provides a broad overview of contemporary biological concepts.
   b. **Prerequisite:** MATH 150, MATH 151, MATH 155 or qualifying score on placement test.
   c. **Designation:** This course is a required class for the biotechnology/bioengineering track.

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction**
      - Prepare students for upper level biology core and elective courses.
      - Present an overview of foundational concepts in contemporary biological science.
      - Help Students become more familiar with the questioning and interactive side of science.

   b. **Student Outcome Addressed**: C1.1 (Foundation in Math/Science).

7. **Brief List of Topics to be Covered:**
   - Structure and synthesis of nucleic acids and proteins
   - Molecular genetics
   - Prokaryotic and eukaryotic cell structure and function
   - Biochemistry of energy transformation
   - Animal and plant development and physiology

1. **BIOL 302 – MOLECULAR AND GENERAL GENETICS**

2. **Credits and Contact Hours:** 4 Credits, 3.5 hours/week lecture, 1 hour/week discussion

3. **Instructor:** Dr. Stephen Miller, Dr. Cynthia Wagner

4. **Required Text Book and Other Supplemental Material:**

   Genetic Analysis, An Integrated Approach, by Sanders and Bowman, 2nd Edition.
   Access Code for *Mastering Genetics,* by Sanders and Bowman, 2015.
   Scitable by Nature Education (online resource for ebook).

5. **Specific Course Information:**

   a. **Course Catalog Description:** Modern principles of heredity have been established through studies at the molecular, cellular and organismic levels. This course explores the fundamental biology of gene structure, organization, expression, and function as deduced from analyses of viral, prokaryotic, and eukaryotic systems and the gene interactions that underlie them. Fundamental genetic principles are applied to the understanding of human heredity and disease, and molecular genetic manipulations are discussed in the context of biotechnology applications.
   b. **Prerequisite:** BIOL 141, BIOL 142, MATH 150 (or MATH 151 or MATH 155), or qualifying score on math placement test. Prerequisite or co-requisite of CHEM 102 or CHEM 124.
   c. **Designation:** This course is a required class for the biotechnology/bioengineering track.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      Students will be able to explain:
      - The principles of heredity in diploid organisms.
      - The structure and function of the key macromolecules involved in the storage and transfer of genetic information.
      - The regulation of gene expression in prokaryotes and eukaryotes.
      - Common methods used to manipulate key biological macromolecules outside the cell, and to reintroduce them into organisms.
      - The use of genetic and molecular methods to study biological questions.
      - Several formats for the presentation of genetic, molecular and general scientific data, and will be able to extract and manipulate information from these formats.
      - The scientific method, and how hypothesis formulation, experimentation, and data interpretation lead to the advance of scientific knowledge.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. Brief List of Topics to be Covered:

- DNA structure, replication, mutation and repair
- Gene structure, transcription and translation
- Control of gene expression
- Mendelian and non-Mendelian genetics
- Genetic misregulation and disease
- Genetics and biotechnology

1. BIOL 303 – CELL BIOLOGY

2. **Credits and Contact Hours:** 4 Credits, 2.5 hours/week lecture, 1 hour/week discussion

3. **Instructor:** Dr. Erin Green, Dr. Michelle Starz-Gaiano

4. **Required Text Book and Other Supplemental Material:**

   Essential Cell Biology, by Alberts, *et al*. (Garland), 4th Edition.

5. **Specific Course Information:**
   a. **Course Catalog Description:** A modern treatment of cell structure and function, with emphasis on the molecular architecture, biochemistry and regulatory mechanisms common to all cells. This course is designed for students interested in the biological sciences, biochemistry and the allied health professions.
   b. **Prerequisite:** BIOL 302, CHEM 102, MATH 150 (or MATH 151 or MATH 155), or qualifying score on math placement test.
   c. **Designation:** This course is a required class in the biotechnology/bioengineering track.

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction:**
      - Know how the structures of key cellular components (including membranes, organelles, the cytoskeleton, and the genetic material) relate to their functions, how these functions are regulated at the molecular level, and how such components work as systems to carry out processes such as cell division, intracellular transport, signaling, and communication with other cells and external agents.
      - Ask the sorts of questions that generate testable hypotheses, how to design experiments that rigorously test those hypotheses, and how to interpret experimental findings.
      - Understand the many types of cell and molecular biological techniques currently in use, and how to apply them to address specific cell and molecular processes.
      - Convey their ideas effectively to others, and to work with and learn from others as they strive toward achieving a common goal.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**
   - Membrane structure
   - Function and transport
   - Molecular mechanisms of energy metabolism and its associated organelles

- The structural and molecular basis for the expression of genetic information
- The organelles involved in the regulation of cell shape and motility
- Selected cell functions, growth, reproduction and their control

1. CHEM 101 – PRINCIPLES OF CHEMISTRY I

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Tara Carpenter, Dr. Diana Hamilton

4. **Required Text Book and Other Supplemental Material:**

   Chemistry: Atoms First, by Burdge/Overby, 2^{nd} Edition
   Calculator

5. **Specific Course Information:**

   a. **Course Catalog Description:** An introduction to chemistry for science majors and other students who require a thorough grounding in the principles of chemistry.
   b. **Prerequisite:** MATH 106, MATH 106Y, MATH 150, MATH 151 or MATH 155
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Provide a basic background and understanding in the theory and principles of chemistry.
      - Develop the skills to apply these principles to a variety of situations.

   b. Student Outcome Addressed: C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Atomic-molecular theory of matter
   - Stoichiometry
   - States of matter
   - Chemical nomenclature
   - Energetics of chemical and physical processes
   - Solutions
   - Periodic properties
   - VSEPR
   - Molecular orbital theory
   - Chemistry of familiar elements

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1. **CHEM 102L – INTRODUCTORY CHEMISTRY LAB I**

2. **Credits and Contact Hours:** 2 Credits, 1 hour/week lecture, 4 hours/week laboratory discussion

3. **Instructor:** Mr. Frank Tyminski

4. **Required Text Book and Other Supplemental Material:**

   Laboratory Manual for Principles of General Chemistry, by J.A. Beran
   Student Lab Notebook
   Safety Goggles

5. **Specific Course Information**:

   a. **Course Catalog Description:** The laboratory course is intended to acquaint students with common laboratory practices used to investigate chemical systems.
   b. **Prerequisite:** CHEM 101 or CHEM 102. Co-requisite: CHEM 102.
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Purpose of the steps and procedures in the experiments both practically and how the procedure relates to theory.
      - Background theory of reaction equations, stoichiometric, kinetic and thermodynamic calculations.
      - Safety awareness of toxic and corrosive properties of chemicals used.
      - Names and formulas of compounds used in the experiments.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Techniques and measurements
   - Basic laboratory operations
   - Percent water in a hydrated salt
   - Molar volume of carbon dioxide
   - Synthesis of potassium alum
   - Limiting reactant
   - Volumetric analysis
   - Antacid analysis
   - Potentiometric analysis
   - Beers Law
   - Le Chatlier's Principle
   - Calorimetry
   - Galvanic Cells
   - Nernst Equation

1. **CHEM 102 – PRINCIPLES OF CHEMISTRY II**

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Diana Hamilton, Mr. Kyle Reddick

4. **Required Text Book and Other Supplemental Material:**

   Chemistry: Atoms First, by Burdge/Overby, 2nd Edition
   Calculator

5. **Specific Course Information:**

   a. **Course Catalog Description:** Principles of chemical and physical equilibrium, liquids and solids, elementary thermodynamics, electron and proton transfer reactions, electrochemistry, chemical kinetics and a further study of the periodic properties of the elements.
   b. **Prerequisite:** CHEM 101
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Provide a basic background and understanding in the theory and principles of chemistry.
      - Give student experience in using and finding information to solve problems.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Principles of chemical and physical equilibrium
   - Liquids and solids
   - Elementary thermodynamic
   - Electron and proton transfer reactions
   - Electrochemistry
   - Chemical kinetics
   - Study of the periodic properties of the elements

1. **CHEM 301 – PHYSICAL CHEMISTRY I**

2. **Credits and Contact Hours:** 4 Credits, 3 hour/week lecture

3. **Instructor:** Dr. Bradley Arnold

4. **Required Text Book and Other Supplemental Material:**

   Atkins' Physical Chemistry, by Atkins and DePaula (any edition)

5. **Specific Course Information:**

   a. **Course Catalog Description:** A lecture course covering the laws of thermodynamics, with emphasis on their application to chemical systems.
   b. **Prerequisite:** CHEM 102, MATH 152 and PHYS 122. Co-requisite: PHYS 122.
   c. **Designation:** This course is a required class in the traditional track.

6. **Specific Goals for the Course:**

   c. **Specific Outcomes of Instruction:**
      - Provide students with a fundamental understanding of the physical descriptions of chemical systems.

   d. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Thermochemistry
   - Equations of state
   - Physical and chemical equilibrium
   - Electrochemistry
   - Kinetic theory of gases
   - Chemical kinetics
   - Theory of rate processes

1. CHEM 302 – PHYSICAL CHEMISTRY II

2. Credits and Contact Hours: 3 Credits, 3 hour/week lecture

3. Instructor: Dr. Lisa Kelly

4. Required Text Book and Other Supplemental Material

Physical Chemistry: Thermodynamics, Structure and Change, by Atkins and DePaula (10th edition)
Molecular Symmetry and Group Theory, by Alan Vincent
Physical Chemistry (Pearson, 2013), by Engel, Thomas and Reid

5. Specific Course Information:

a. **Course Catalog Description:** This class serves to provide its students with a fundamental understanding of the quantum mechanical description of chemical systems and their spectroscopy. A detailed description of the quantum mechanics will be presented and applied to several important model systems. This class builds on freshman chemistry and thermodynamics, CHEM 301, and is designed to give students the background necessary to understand the experiments presented in CHEM 312L -Advanced Laboratory II.
b. **Prerequisite:** CHEM 301.
c. **Designation:** This course is a required class in the traditional track.

6. Specific Goals for the Course:

a. **Specific Outcomes of Instruction:**
   - Develop an appreciation for where and how quantum mechanics arose.
   - Know how it is used to provide the basis for atomic and molecular structure that we have come to learn about since freshman chemistry.
   - Know how spectroscopy is used to probe these structures.

b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. Brief List of Topics to be Covered:

- Introduction to quantum mechanics
- Types of motion
- Electronic structure of atoms
- Symmetry and group theory
- Molecular spectroscopy: rotational, vibrational and electronic
- Molecular structure
- Polyatomics

1. **CHEM 303 – PHYSICAL CHEMISTRY FOR THE BIOCHEMICAL SCIENCES**

2. **Credits and Contact Hours:** 3 Credits, 2 hours/week lecture

3. **Instructor:** Dr. Christopher Geddes

4. **Required Text Book and Other Supplemental Material:**

   Physical Chemistry, by Peter Atkins (9th edition)

5. **Specific Course Information:**
   a. **Course Catalog Description:** This course is designed to familiarize students with the qualitative and quantitative concepts of physical chemistry as they apply to biochemical systems and macromolecules.
   b. **Prerequisite:** CHEM 351, MATH 152 and PHYS 112 or PHYS 122. **Corequisite:** PHYS 112 or PHYS 122.
   c. **Designation:** This course is a required class in the biotechnology/bioengineering track and in the environmental track.

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction:**
      - Understanding of biochemical system concepts and principles of physical chemistry.
      - Train your mind to think using principles of chemistry.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**
   - General equilibrium thermodynamics emphasizing biochemical applications
   - Ligand binding
   - Biological oxidation-reduction reactions
   - Membranes
   - Colligative properties and transport properties
   - Kinetics including elementary rate laws
   - Reaction mechanisms and activated processes
   - Relaxation and enzyme kinetics
   - An introduction to quantum chemistry
   - Electronic structure and bonding
   - Molecular spectroscopy (including vibrational, electronic and magnetic spectroscopy)

1. CHEM 311L – ADVANCED LABORATORY I

2. **Credits and Contact Hours:** 3 Credits, 1 hour/week lecture, 8 hours/week laboratory

3. **Instructor:** Mr. Daniel Rowlands

4. **Required Text Book and Other Supplemental Material:**

   Experiments in Physical Chemistry, by Garland, Nibler and Shoemaker (8^{th} edition)
   Graph paper laboratory notebook
   Safety glasses with side shields or safety googles

5. **Specific Course Information:**

   a. **Course Catalog Description:** Laboratory exercises encompassing experimental problems in physical, inorganic, synthetic and instrumental analytical chemistry.
   b. **Prerequisite/Co-requisite:** CHEM 301.
   c. **Designation:** This course is a required class in the traditional track.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - How to build, calibrate, and program computer-controlled scientific instrumentation
      - How to design an experiment to collect data to confirm or reject a specific hypothesis
      - How to analyze, report, and explain the data from such an experiment
      - How to work effectively in an entrepreneurial small group to accomplish all of the above objectives.
   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Analysis of data
   - The techniques of measurement
   - Computer-interfaced instrumentation
   - Gases
   - Electronics
   - MATLAB
   - Calorimetry
   - Viscometry
   - Voltammetry
   - Differential Thermal Analysis
   - Lattice Energy
   - Gas Transport
   - Writing Lab Reports

1. CHEM 351L – ORGANIC CHEMISTRY LABORATORY I

2. **Credits and Contact Hours:** 0 Credits, 1 hour/week lecture, 4 hours/week laboratory

3. **Instructor:** Dr. Harry (Mark) Perks

4. **Required Text Book and Other Supplemental Material:**

   Chem 351L Laboratory Manual, UMBC, by J.W. Lehman

5. **Specific Course Information:**

   a. **Course Catalog Description:** Companion laboratory course to CHEM351.
   b. **Prerequisite:** CHEM 102, CHEM 102L and CHEM 351. Co-requisite: CHEM 351.
   c. **Designation:** This course is a required class in the traditional track.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Techniques to separate, purify, and characterize organic compounds.
      - Perform fundamental functional group transformations.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Proper handling of experimental apparatus
   - Precautions for conducting the experiments safely and awareness of toxic and corrosive properties of chemicals used.
   - Names and structures of the compounds you work with.
   - The background theory of stereochemistry, regiochemistry, equations and mechanism.
   - Application of experiments accomplishing synthetic steps to analogous reactions.
   - The purpose of the steps in the procedure of the experiments both practically and how the procedure relates to theory.
   - Stoichiometry calculations and general laboratory practice.
   - The physical properties of the compounds.

1. **CHEM 351 – ORGANIC CHEMISTRY I**

2. **Credits and Contact Hours:** 3 Credits, 3 hours/week lecture

3. **Instructor:** Dr. Tiffany Gierasch, Dr. Harry (Mark) Perks

4. **Required Text Book and Other Supplemental Material:**

   Organic Chemistry, by David Klein, John Wiley and Sons (2^{nd} edition)

5. **Specific Course Information:**

   a. **Course Catalog Description:** The chemistry of aliphatic and aromatic compounds, including bonding, stereochemistry and reactions of functional groups, reaction mechanisms, synthetic methods and characterization of organic molecules.
   b. **Prerequisite:** CHEM 102.
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Describe the bonding in organic compounds and predict physical properties related to molecular geometry and molecular dipoles.
      - Draw and rank the relative importance of resonance structures and use curved arrows to show how to get from one resonance structure to another.
      - Use the concept of resonance to explain relative stability and reactivity.
      - Write the products of an acid-base reaction and use curved arrows to depict the movement of electrons in the reaction.
      - Rank the relative stability of acids and bases and predict whether or not a reaction is favorable.
      - Convert between different representations of organic molecules such as Lewis structures, condensed structures, bond-line formulas, Newman projections, and chair conformations.
      - Depict and rank the relative stability of different molecule conformations.
      - Provide an IUPAC name for a compound containing the functional groups (alkanes, alkenes, alkynes, alcohol, alkyl halides), including stereochemical descriptors where appropriate.
      - Determine whether two different structures are the same molecule, enantiomers, diastereomers, constitutional isomers, or different molecules that are unrelated.
      - Determine whether a molecule is chiral, meso, or achiral but not meso.
      - Predict whether or not compounds and mixtures of compounds will be optically active and use ee% to describe the composition of mixtures of enantiomers.
      - Rank the stability of C-H bonds.

- Write a mechanism for free-radical halogenation and explain the relative reactivity & selectivity of chlorination versus bromination.
- Identify nucleophiles and electrophiles and use that knowledge to help draw curved arrows that point in the right direction.
- Draw a mechanism for an SN1/SN2/E1/E2 reaction and describe the rate expression.
- Describe the ideal conditions (substrate branching, leaving group, reagent, solvent) for an SN1/SN2/E1/E2 reaction and describe relative reaction rates when these factors are varied.
- Predict which reaction mechanism (SN1/SN2/E1/E2) is most likely for a given reaction and draw the appropriate product
- Understand the reactivity of the pi bond compared to a sigma bond; especially the pi bonds use as a nuclephile and how that leads to addition reactions with electrophiles.
- In the balance between elimination and addition to alkenes, describe how to favor one reaction over the other.
- In reactions where more than one regioisomer or stereoisomer is possible, predict the major product.
- Explain the acidity of a terminal alkyne and the use of its conjugate base to make new carbon-carbon bonds, including limitations based on substrate structure.
- Identify a reaction as a reduction, an oxidation, or neither.
- Predict which alcohols can be oxidized to carbonyl compounds and which alcohols can be made by reducing carbonyl compounds.
- Use curved arrows to write a mechanism for a known, and new reaction.
- For a known reaction, provide the product, starting material or reagent, if given the other two variables.
- Propose short syntheses by providing reagents necessary to convert from a starting material to a product involving more than one individual reaction.

b. **Student Outcomes Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

- A review of general chemistry: electrons, bonds and molecular properties.
- Molecular representations
- Acids and bases
- Alkanes and cycloalkanes
- Stereoisomerism
- Chemical reactivity and mechanisms
- Substitution reactions
- Alkenes: structure, preparation via elimination reaction and addition reactions
- Alkynes
- Radical reactions
- Synthesis
- Alcohols and phenols

1. CHEM 352 – ORGANIC CHEMISTRY II

2. Credits and Contact Hours: 3 Credits, 3 hours/week lecture

3. Instructor: Dr. Tiffany Gierasch

4. Required Text Book and Other Supplemental Material:

Organic Chemistry, by David Klein, John Wiley and Sons (2^{nd} edition)

5. Specific Course Information:

a. **Course Catalog Description:** Continuation of CHEM 351 - The chemistry of aliphatic and aromatic compounds, including bonding, stereochemistry and reactions of functional groups. Reaction mechanisms, synthetic methods and characterization of organic molecules.
b. **Prerequisite:** CHEM 102 and CHEM 351.
c. **Designation:** This course is a required class in the biotechnology/bioengineering track and in the environmental track.

6. Specific Goals for the Course:

a. **Specific Outcomes of Instruction:**
    - Use curved arrows to write a mechanism for a known, and new reaction.
    - For a known reaction, provide the product, starting material or reagent, if given the other two variables.
    - Propose short syntheses by providing reagents necessary to convert from a starting material to a product involving more than one individual reaction.
    - In reactions where more than one regioisomer or stereoisomer is possible, predict the major product.
    - Explain the relationship between stability and reactivity and use it to predict whether or not a reaction will be favorable.
    - For reactions that can occur in either acid or base, draw a mechanism that matches the reaction conditions.
    - Identify if a reaction is an oxidation, a reduction, or neither.
    - Explain the relative stability of ethers compared to the relative reactivity of epoxides.
    - Use molecular orbital theory to explain electron delocalization in conjugated compounds.
    - Use molecular orbital theory to predict whether a compound/ion is aromatic, anti-aromatic, or non-aromatic.
    - Explain how the electronic properties of substituents affect the regiochemistry of aromatic substitution reactions.
    - Predict whether the addition of a nucleophile to a carbonyl will result in an addition reaction or a substitution reaction.

- Predict whether the addition of a nucleophile to a carbonyl will be reversible or irreversible.
- Predict whether or not a substitution reaction involving a carboxylic acid derivative is favorable or unfavorable.
- Explain the acidity of carboxylic acids and rank the relative acidity of oxygen-containing compounds.
- Explain the basicity of amines and rank the relative acidity of nitrogen-containing compounds.
- Explain the acidity of the position alpha to a carbonyl and rank the relative acidity of the alpha position for various carbonyl compounds
- Explain how an enolate can be used as a nucleophile to make new carbon-carbon bonds.

b. Student Outcome Addressed: C1.1 (Foundation in Math/Science)

7. Brief List of Topics to be Covered:

- Ethers and epoxides: thiols and sulfides
- Infrared spectroscopy and mass spectrometry
- Nuclear magnetic resonance spectroscopy
- Conjugated pi systems and pericyclic reactions
- Aromatic compounds
- Aromatic substitution reactions
- Aldehydes and ketones
- Carboxylic acids and their derivatives
- Alpha carbon chemistry: enols and enolates
- Amines

1. **CHEM 437 – Comprehensive Biochemistry I**

2. **Credits and Contact Hours:** 4 Credits, 4 hours/week lecture

3. **Instructor:** Dr. Elsa Garcin, Dr. Sarah Kohler

4. **Required Text Book and Other Supplemental Material:**

   Biochemistry, by Garrett and Grisham (5^{th} edition)

5. **Specific Course Information:**

   a. **Course Catalog Description:** A thorough introduction to the principles of modern biochemistry.
   b. **Prerequisite:** CHEM 352.
   c. **Designation:** This course is a required class in the biotechnology/bioengineering track.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Understand the central and essential importance of water as polar solvent in biological chemistry; Understand the classification of weak and strong acid/bases; understand titrations curves, appreciate the use of buffer in biochemistry and in cells.
      - Understand the principal laws of thermodynamics and how these dictate the behavior of chemical and biochemical substances.
      - Know the major types of biochemical molecules and their building blocks, including amino acids, proteins, nucleotides, nucleic acids, lipids, and carbohydrates; and know their characteristics that make them crucial for life. Understand chromatography and detection techniques to separate/analyze complex mixtures.
      - Understand the importance of the 3-D arrangements of atoms in biomolecules, including amino acids, protein nucleic acids, lipids, and carbohydrates; and understand how these 30 arrangements are created and stabilize. Students should also know and understand the different types of interactions between ions, atoms, and molecules.
      - Know the structure of DNA and RNA and why these molecules have different roles in the storage and decoding of the information of heredity and cell function.
      - Know how recombinant DNA technology works.
      - Describe how enzymes work and know how to determine basic enzyme kinetics

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Properties of water

- Thermodynamics in biochemistry
- Amino acids
- Protein primary structure
- Protein 3D structure
- Nucleotides and nucleic acids
- DNA/RNA structure
- Cloning
- Carbohydrates and glycoconjugates
- Lipid structure
- Membrane structure
- Enzyme kinetics, specificity, mechanism and regulation
- Molecular motors

1. **ENGL 100 – COMPOSITION**

2. **Credits and Contact Hours:** 3 Credits, 2.5 hours/week lecture

3. **Instructor:** Ms. Kimberly Banks, Mr. Ryan Bloom, Mr. Arnold Blumberg, Ms. Margie Burns, Ms. May Chung, Mr. Brian Dunnigan, Mr. James Harris, Mr. Ernest Kiehne, Mr. Joseph Nash, Dr. Tanya Olson, Dr. Nicole Pekarske, Ms. Diane Putzel, Ms. Victoria Rudacille, Ms. Sally Shivnan, Mr. Christopher Varlack, Ms. April Walters, Ms. Olga Ware

4. **Required Text Book and Other Supplemental Material:**

   They Say, I Say – with readings, by Gerald Graff, Cathy Birkenstein and Russel Durst
   The Little Seagull Handbook, by Richard Bullock and Francine Weinberg
   Not In My Neighborhood: How Bigotry Shaped A Great American City, by Antero Pietila

5. **Specific Course Information:**

   a. **Course Catalog Description:** A course in critical thinking, reading, and composing, with an emphasis on integrating academic research and documentation. Students read and produce work for a variety of purposes and audiences, focusing on strategies for researching, organizing, drafting, sharing, and revising.
   b. **Prerequisite:** Qualifying score on placement test.
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Identify rhetorical concepts such as purpose, audience, context, and genre in texts they encounter
      - Address these same concepts effectively in their own compositions, identifying and focusing on purpose, responding to different audiences and contexts, and composing in different genres
      - Distinguish that making choices about the appropriate rhetorical approach for a composing task is based on the discipline, discourse, or setting, in the university and beyond
      - Demonstrate the use of writing and reading for inquiry, learning, thinking, and communicating
      - Approach a composition assignment as a series of tasks, including finding, evaluating, analyzing, and synthesizing appropriate primary and secondary sources
      - Describe research as a question-guided process and as an ongoing conversation to which they can contribute
      - Evaluate sources for credibility, bias, quality of evidence, and quality of reasoning

- Integrate, in their work, their own ideas with those from sources
- Support their assertions with appropriate evidence, and respond effectively, in their work, to differing viewpoints
- Discuss the relationships between language, knowledge, and power
- Analyze and articulate their own processes in responding to, and composing, texts
- Generalize that it usually takes multiple drafts to create and complete a successful text
- Employ flexible strategies for generating, researching, organizing, drafting, revising, editing, and proof-reading
- Assess writing as a continuing process that permits writers to use later invention and re-thinking to revise their work
- Describe the collaborative and social aspects of writing processes
- Critique their own and others' works effectively
- Demonstrate knowledge of genre conventions ranging from structure and paragraphing to tone and mechanics
- Use academic documentation (e.g. MLA, APA) effectively, and define the logic underlying its conventions
- Control such surface features as syntax, grammar, punctuation, and spelling, so that minor departures do not interfere with reading ease or comprehension
- Show facility in using electronic environments for drafting, reviewing, revising, editing, and sharing texts
- Compare how print, electronic, and hybrid texts affect reading, researching, and composing processes
- Use technology, old and/or new, strategically, in order to enhance the text for the audience
- Locate, evaluate, organize, and use research material from a variety of sources, including electronic sources such as library databases, other official databases (e.g., federal government databases), and informal electronic networks and internet sources.

b. None of the student outcomes listed in Criterion 3 are directly addressed in this course.

7. Brief List of Topics to be Covered:

- Rhetorical knowledge
- Critical thinking, reading, research and composing
- Processes
- Knowledge of conventions
- Composing in multiple environments

1. MATH 151 – CALCULUS AND ANALYTIC GEOMETRY I

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Kalman Nanes, Mr. Joshua Hudson, Ms. Xinxuan Li and Mrs. Bonny Tighe

4. **Required Text Book and Other Supplemental Material:**

   Calculus, Early Transcendentals, by James Stewart, 7th Edition
   Calculator

5. **Specific Course Information:**

   a. **Course Catalog Description:** This course will cover techniques and applications of integral calculus, including integration by parts, trigonometric substitution, sequences and series, Taylor series, and calculus in parametric equations and polar coordinates.
   b. **Prerequisite:** MATH 150 or qualifying score on placement test
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - To introduce the core concepts of limits, differentiation and integration
      - Be able to apply these concepts to solve problems.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

   - Limits
   - Continuity
   - The rate of change
   - Derivatives
   - Differentiations formulas for algebraic, trigonometric, logarithmic and exponential functions
   - Maxima and minima
   - Integration and computation of areas
   - The Fundamental Theorem of Calculus
   - Areas and volumes of solids of revolution

1. **MATH 152 – CALCULUS AND ANALYTIC GEOMETRY II**

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Brian Dean, Dr. Cheyne Homberger, Mrs. Bonny Tighe

4. **Required Text Book and Other Supplemental Material:**

   Calculus, Early Transcendentals, by James Stewart, 7th Edition
   Calculator

5. **Specific Course Information:**
   - a. **Course Catalog Description:** This course will cover techniques and applications of integral calculus, including integration by parts, trigonometric substitution, sequences and series, Taylor series, and calculus in parametric equations and polar coordinates.
   - b. **Prerequisite:** MATH 151, MATH 151H, MATH 141 or MATH 155B
   - c. **Designation:** This course is a required class.

6. **Specific Goals for the Course**
   - a. **Specific Outcomes of Instruction:**
     - Comprises the main ideas of Integral Calculus, along with material regarding infinite series, parametric equations and polar coordinates.
     - Using the concept of a "limit", consider the idea of the area under the graph of a function as the limit of a summation of rectangles, called a "definite integral". See that the definite integral can be viewed as the inverse of the derivative.
     - Develop a large collection of techniques for computing integrals.
     - Learn applications of the definite integral to physical problems such as computation of volumes and describing the motion of an object.
     - This course builds upon ideas from MATH 151, Calculus I, where students will have become familiar will key concepts of limits, the "derivative" as the limit of a difference quotient, and various techniques for computing derivatives.
   - b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**
   - Inverse functions
   - Methods of integration
   - Improper integrals
   - Hyperbolic functions
   - Sequences and infinite series
   - Power series
   - Taylor series

- Conic sections
- Polar coordinates
- Applications

1. MATH 221 – INTRODUCTION TO LINEAR ALGEBRA

2. **Credits and Contact Hours:** 3 Credits, 2.5 hours/week lecture

3. **Instructors:** Drs. Jacob Kogan, James Lo, Keith Pardue, Florian Potra & Stephen Thompson

4. **Required Text Book and Other Supplemental Material:**

   Linear Algebra and Its Applications, D.C. Lay, 4^{th} Edition.
   Calculator

5. **Specific Course Information:**
   a. **Course Catalog Description:** Linear Algebra deals with systems of linear equations, their fundamental properties and transformations of vector spaces. The basic objects of the course are vectors and matrices. Linear algebra techniques are widely used in many areas, such as mathematics, engineering, economics and finance. They are also cornerstones for a variety of advance classes in science and engineering. The course will describe basic concepts and tools of linear algebra.
   b. **Prerequisite:** MATH 141, MATH 151 or MATH 380
   c. **Designation:** This course is an elective class.

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction**
      - Understand to characterize existence, uniqueness and solution sets of systems of linear equations via the row reduction algorithm
      - to perform matrix operations, including inverse and determinant computations
      - to characterize vector spaces or subspaces, and determine their dimension and matrix ranks
      - to compute eigenvectors and eigenvalues, and perform matrix diagonalization
      - concepts of orthogonality and orthogonal bases, carry out orthogonal transformations and projections.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**
      - The algebra of linear equations and matrices
      - The geometry of vector spaces
      - Algorithms for solving linear equations

1. MATH 225 – INTRODUCTION TO DIFFERENTIAL EQUATIONS

1. **Credits and Contact Hours:** 3 Credits, 2.5 hours/week lecture

2. **Instructor:** Drs. Brian Dean, Kathleen Hoffman and James Lo

3. **Required Text Book and Other Supplemental Material:**

   An Introduction to Differential Equations and Their Applications, Stanley J. Farlow, 2006.
   Calculator

4. **Specific Course Information:**
   a. **Course Catalog Description:** Apply the concepts and techniques learned in Calculus I and II to the study of differential equations (equations involving functions and their derivatives) and their application.
   b. **Prerequisite:** MATH 142 or MATH 152
   c. **Designation:** This course is a required class.

5. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction:**
      - Understand and remember the key ideas, concepts, definitions, and theorems of the subject. Examples in this course include the classification of differential equations, solvability and uniqueness theorems, and analytical solution techniques.
      - Be able to apply mathematical theorems and computational algorithms correctly to answer questions, and interpret their results correctly, including potentially non-unique solutions or breakdowns of algorithms. Examples include choosing among several methods to solve a differential equation and how to react to intermediate solutions found that may indicate a breakdown of the method.
      - Appreciate the power of mathematical abstraction and understand how mathematical theory is developed. Classical example of mathematical abstraction in this class are the existence and uniqueness theorem for first-order initial value problems and the theorem that governs the number of fundamental solutions for a linear ordinary differential equation of a given order.
      - Be able to communicate effectively by discussing mathematical ideas and algorithms with the instructor as well as other students.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

6. **Brief List of Topics to be Covered:**
      - Solutions of first- and second order linear differential equations
      - Non-linear exact and separable equations

- Integrating factors
- Homogeneous equations
- Higher-order linear equations
- Initial and boundary value problems
- Solutions as functions of the equation parameters
- Laplace transforms
- Power series solutions for Bessel and Legendre equations
- Difference equations and numerical methods

1. MATH 251 – MULTIVARIABLE CALCULUS

1. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 1 hour/week discussion

2. **Instructor:** Dr. Kalman Nanes, Dr. Stephen Thompson

3. **Required Text Book and Other Supplemental Material:**

   Multivariable Calculus, James Stewart, 7^{th} Edtion
   Calculator
   Ruler

4. **Specific Course Information:**

   a. **Course Catalog Description:** Demonstration of how single-variable calculus generalizes to higher dimensions.
   b. **Prerequisite:** MATH 142 or MATH 152
   c. **Designation:** This course is a required class.

5. **Specific Goals for the Course:**

   a. **Specific Outcomes of Instruction:**
      - Work with vectors and 3D coordinate systems.
      - Visualize lines, planes curves and surfaces in 3D space.
      - Generalize concepts learned in single-variable differential and integral calculus to the setting of vector functions and space curves.
      - Use concepts of calculus in these new, generalized settings in various applications.
      - Develop analytic and problem-solving skills, including the ability to break a complicated task into reasonable steps.

   b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

6. **Brief List of Topics to be Covered:**

   - Parametric and polar functions
   - Vectors, lines planes and surfaces in three dimensions
   - Vector functions and their derivatives
   - Partial derivatives
   - Gradients
   - Directional derivatives
   - Maxima and minima
   - Lagrange multipliers
   - Multiple integrals
   - Area, volume, surface area, integration in different coordinate systems
   - Line integral
   - Green's, Stokes and divergence theorems

1. PHYS 121 – INTRODUCTORY PHYSICS I

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Lili Cui

4. **Required Text Book and Other Supplemental Material:**

    Physics for Scientists and Engineers, by Tipler and Mosca, 6th ed., Volume 1
    FlipItPhysics (electronic pre-lecture and homework assignments)
    Clicker (Turning Technologies RFC-03, can be purchased from UMBC bookstore)
    Calculator

5. **Specific Course Information:**
    a. **Course Catalog Description:** This course emphasizes classical mechanics.
    b. **Prerequisite/Co-requisite:** MATH 151
    c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**
    a. **Specific Outcomes of Instruction:**
        - Solve 1-dimension and 2-dimension kinematics motion problems
        - Apply Newton's laws to solve problems related to motion and force
        - Apply energy principle to solve mechanics problems
        - Apply conservation of momentum to solve problems related to collision
        - Apply Newton's 2nd law for rotation to solve rotational dynamics problems
        - Solve problems related to static equilibrium
        - Apply conservation of angular momentum to solve problems
        - Apply Newton's laws and energy principle to solve problems related to simple harmonic motion

    b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**
    - Force
    - Particle Kinematics and Dynamics
    - Equilibrium
    - Newton's Laws of Motion and Gravitation
    - Rotational Motion
    - Collisions
    - Momentum
    - Energy and Conservation Laws

1. PHYS 122 – INTRODUCTORY PHYSICS II

2. **Credits and Contact Hours:** 4 Credits, 3 hours/week lecture, 2 hours/week discussion

3. **Instructor:** Dr. Eric Anderson

4. **Required Text Book and Other Supplemental Material:**

   Physics for Scientists and Engineers, by Tipler
   FlipItPhysics (electronic pre-lecture and homework assignments)
   Clicker (Turning Technologies RFC-03, can be purchased from UMBC bookstore)
   Calculator

5. **Specific Course Information:**
   a. **Course Catalog Description:** This course emphasizes electricity, magnetism, heat and thermodynamics.
   b. **Prerequisite:** PHYS 121, MATH 152 Co-requisite: MATH 152
   c. **Designation:** This course is a required class.

6. **Specific Goals for the Course:**
   a. **Specific Outcomes of Instruction:**
      - Apply the first law of thermodynamics, ideal gas law, and ideas of molar heat capacity to thermal processes with ideal gases.
      - Analyze the performance of thermodynamic cycles.
      - Use Coulomb's law and the principle of superposition to find electric fields of charged particles and determine forces on charged particles.
      - Apply Gauss's law to find electric fields of symmetric charge distributions and infer charge distributions on conductors.
      - Qualitatively and quantitatively reason with electric potential and electric potential energy; determine electric potential difference from electric field.
      - Apply the definition of capacitance and Kirchoff's rules to find charges and voltages in circuits containing batteries and capacitors.
      - Apply Ohm's law and Kirchoff's rules to find currents, voltages, and power in circuits containing batteries and resistors.
      - Analyze charging and discharging processes in circuits containing batteries, resistors, and capacitors, i.e, determine charges, currents, and voltages as a function of time and in limiting cases of small and large times.
      - Determine the magnetic force on a moving charged particle and its resulting motion, the magnetic force on a current-carrying wire, and apply ideas of torque and potential energy to current loops in magnetic fields.
      - Apply results of the Biot-Savart law and the superposition principle to determine magnetic fields due to infinite straight wires and current loops.

- Apply Faraday’s law to determine the emf arising from a changing magnetic flux.

b. **Student Outcome Addressed:** C1.1 (Foundation in Math/Science)

7. **Brief List of Topics to be Covered:**

- Thermodynamics
- Electricity
- DC Circuits
- Magnetism
- Faraday’s Law and Induction

Appendix B – Faculty Vitae

1. Name: LEE BLANEY

2. Education
Ph.D., Civil Engineering, The University of Texas at Austin, 2011.
M.S., Environmental Engineering, Lehigh University, 2007.
B.S., Environmental Engineering, Lehigh University, 2005.

3. Academic Experience
UMBC, Assistant Professor, 2011-present (full time).

4. Non-Academic Experience
Kenai Watershed Forum, 2004 (full time). Summer intern in environmental organization.

5. Certifications or Professional Registrations
Engineer in Training, 2010.

6. Current Membership in Professional Organizations
American Chemical Society (ACS).
American Water Works Association (AWWA).
Association of Environmental Engineering and Science Professors (AEESP).
Engineers Without Borders (EWB).
International Water Association (IWA).
Water Environment Federation (WEF).

7. Honors and Awards
UMBC Donald Creighton Memorial Faculty Award, 2015.
The University of Texas at Austin THRUST Fellowship, 2007-2011.
National Science Foundation Graduate Research Fellowship, 2006-2011.
The University of Texas at Austin University Fellowship, 2007-2008.
National Science Foundation East Asia and Pacific Summer Institute Fellow, 2007.
US Environmental Protection Agency Phase II P3 Award, 2007.
National Academy of Engineering Grainger Challenge Silver Award, 2007.

8. Service Activities
Member, Goldwater scholarship selection committee, 2015-present.
Member, HHMI/MARC U*STAR Steering Committee, 2015-present.
Member, Center for Women in Technology Advisory Board, 2015-present.
Member, COEIT Grand Challenges Scholars Program Faculty Advisory Board, 2015-present.
Member, Shriver Center Faculty Advisory Board, 2014-present.
Associate Editor, Current Pollution Reports, Springer, 2014-present
Chair, Co-chair, AEESP Membership and Demographics Committee, 2013-present.
Member, Undergraduate Research Award Selection Committee, 2013-present.
Guest Associate Editor, Journal of Hazardous Materials, 2015.
Member, Secretary, Engineers Without Borders Faculty Leadership Council, 2013-2015.
Member, US Delegation to Joint Workshop on Remediation of Pesticides and Metal Contamination (Delhi, India), January 15-18, 2014

Member, US Delegation to NSF-sponsored Indo-US Workshop on Water Quality and Sustainability (Chennai, India), January 7-11, 2013
Maryland State Representative, Engineers Without Borders USA, 2012-2013.

9. Publications and Presentations

S. Snowberger, H.A. Adejumo, K. He, K.P. Mangalgiri, M. Hopanna, A.D. Soares, and L. Blaney. "Direct photolysis of fluoroquinolone antibiotics at 253.7 nm: Specific reaction kinetics and formation of equally-potent fluoroquinolone antibiotics," Environmental Science & Technology 50(17): 9533-9542, August 2016.

L. Blaney, R. Kandiah, J.J. Ducoste, J.A. Perlinger, and S.L. Bartelt-Hunt. "Assessing the growth and demographics of environmental engineering students and faculty from 2005 to 2013," Environmental Engineering Science 33(8): 578-590, July 2016.

Z. Hopkins and L. Blaney. "An aggregate analysis of personal care products in the environment: Identifying the distribution of environmentally-relevant concentrations," Environment International 92-93: 301-316, July 2016.

A. Van Epps and L. Blaney. "Pharmaceuticals and personal care products in wastewater: Implications for urban water reuse" in Handbook of Urban Water Reuse edited by Saeid Eslamian. Francis and Taylor (CRC Group), December 2015.

A. Adak, K. Mangalgiri, J. Lee, and L. Blaney. "UV irradiation and UV-H_2O_2 advanced oxidation of the roxarsone and nitarsone organoarsenicals," Water Research 70(3): 74-85, March 2015.

K.P. Mangalgiri, K. He, and L. Blaney. "Emerging contaminants: A potential human health concern for sensitive populations," PDA Journal of Pharmaceutical Science and Technology 69(2): 1-4, March 2015.

K. He, A.D. Soares, H. Adejumo, M. McDiarmid, K. Squibb, and L. Blaney. "Detection of a wide variety of human and veterinary fluoroquinolone antibiotics in municipal wastewater and wastewater-impacted surface water," Journal of Pharmaceutical and Biomedical Analysis 106: 136-143, March 2015.

K. Mangalgiri, A. Adak, and L. Blaney. "Organoarsenicals in poultry litter: Detection, fate, and toxicity," Environment International, 75(2): 68-80, February 2015.

K. He and L. Blaney. "Systematic optimization of an SPE with HPLC-FLD method for fluoroquinolone detection in wastewater," Journal of Hazardous Materials 282: 96-105, January 2015.

L. Blaney. "Ozone treatment of antibiotics in water" in Water Reclamation and Sustainability edited by Satinder Ahuja. John Wiley & Sons, Inc., January 2014.

Z. Hopkins and L. Blaney. "A novel approach to modeling the reaction kinetics of tetracycline antibiotics with aqueous ozone," Science of the Total Environment 468-469(1): 337-344, January 2014.

1. Name: **MARIAJOSE CASTELLANOS**

2. Education
Ph.D., Chemical Engineering, Cornell University, Ithaca NY, 2005.
B.S., Chemical Engineering, Universidad Nacional Autónoma de México, Mexico City, 1999.

3. Academic Experience
UMBC, Senior Lecturer, 2016-present (full time).
UMBC, Lecturer, 2013-2016 (full time).
UMBC, Assistant Professor, 2005-2013 (full time).

4. Non-Academic Experience
None

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
American Society of Engineering Education
American Institute of Chemical Engineering

7. Honors and Awards
2006 Pew Scholar, Nominee, UMBC.
2006 HENAAC, Role Model of the Week, UMBC.
2006 Searle Scholar University System of Maryland Nominee, UMBC.
2005 HENAAC, Distinguished Nominee, UMBC.
2003 Best Teaching Assistant, School of Chemical and Biomolecular Engineering, Cornell University.
2000 First place at undergraduate level research original thesis work in the area of Petroleum Refining, Gas Processing and Petrochemistry.
1999 Gabino Barreda Medal, Valedictorian, Recognition to the University Merit, UNAM.
1998 Asociación Nacional de Facultades y Escuelas de Ingeniería. Best graduate of the Chemical Engineering Institutions in Mexico

8. Service Activities
UNIVERSITY
Undergraduate Research Award Committee, September 2015 – present.
SHPE UMBC Chapter Advisor, January 2015 – present.
TLST curriculum committee (College of Natural and Mathematical Sciences) November 2012-present.
Faculty Senate Representative Fall 2008, Fall 2009 – present.
Faculty Senate Executive Committee, 2009 - present.

DEPARTMENT
Undergraduate Program Director January 2016– present.
Undergraduate Program Director (co-UPD with Dr.Taryn Bayles) Aug 2015 – Dec 2015.

Undergraduate Committee, August 2013-present.
Undergraduate Academic Advisor August 2014 – present.
Graduate Program Director, August 2014 – August 2015.
Graduate Committee UMBC, January 2005- August 2015.
AIChE Student Chapter Advisor August 2015 – present.

PROFESSION
AIChE Section 15 C Director, 2012 – 2014.
AIChE Section 15C Vice Chair 2010 and Chair 2011.
ACS BIOT Division: Session Chair: 2010, 2009, 2008, 2006. Poster Chair: 2005. Judge for oral sessions: 2006, poster sessions: 2005.
AIChE Section 15 Food and Bioengineering: Session Chair: 2011, 2009, 2008, 2006, 2007. Poster Chair: 2007. Judge for Undergraduate Students Poster Presentations, 2005.
Engineering Foundation Biochemical Engineering Conference Poster Chair: 2007. Organized the division ~ posters and coordinated judging for the Best MERCK Award poster. Session Chair: 2011.
Engineering Foundation Metabolic Engineering Conference Session Chair: 2006.
Reviewer: NSF, AIChE Journal, Journal of Industrial Microbiology & Biotechnology, Molecular Microbiology, Journal of Theoretical Biology, BioSystems, and Biotechnology & Applied Biochemistry.

9. Publications and Presentations
Peer –reviewed Publications
N. P. Wilson, Gates, B. M. Castellanos. Modeling the short time-scale dynamics of β-amyloid-neuron interactions, Journal of Theoretical Biology. 2013 Aug 21, (331): 28-37.
M. Castellanos, K. Kushiro, S. Lai, M.L. Shuler. A genomically/chemically complete module for synthesis of lipid membrane in a minimal cell. Biotechnology and Bioengineering, 2007, 97 (2), 397-409.
S. Browning, M.Castellanos, M.L. Shuler, Robust control of initiation of prokaryotic chromosome replication: Essential considerations for a minimal cell, Biotechnology and Bioengineering, 2004, Dec 5, 88, (5), 575-584.
M.Castellanos, D. Wilson, M.L.Shuler, A modular minimal cell: pyrimidine and purine transport and metabolism, Proceedings of the National Academy of Sciences, 2004, April 27; 101(17), 6681-6686.
Peer –reviewed Conference Proceedings
Castellanos, M., & Enszer, J. A. (2015, June), **Promoting Metacognition through Writing Exercises in Chemical Engineering** Paper presented at 2015 ASEE Annual Conference and Exposition, Seattle, Washington. 10.18260/p.24613
Enszer, J. A., & Castellanos, M. (2013, June), **A Comparison of Peer Evaluation Methods in Capstone Design** Paper presented at 2013 ASEE Annual Conference, Atlanta, Georgia. https://peer.asee.org/19046
Castellanos, M., & Enszer, J. A. (2013, June), **Promoting Metacognition through Reflection Exercises in a Thermodynamics Course** Paper presented at 2013 ASEE Annual Conference, Atlanta, Georgia. https://peer.asee.org/22384

1. Name: **GAUTOM K. DAS**

2. Education

Ph.D., Chemical Engineering, Nanyang Technological University, Singapore, 2010.
B.S., Chemical Engineering, Bangladesh University of Engineering and Technology, Bangladesh, 2004.

3. Academic Experience

UMBC, Lecturer, 2016-present (full time).
University of California, Davis, Postdoc, 2015- 2016, 2012-2014 (full time).
Rice University, Research Scientist and Lecturer, 2014-2015 (full time).
University of Victoria, Canada, Research Fellow, 2010-2011 (full time).

4. Non-Academic Experience

Chevron, Operation Specialist, 2005 (full time). Worked as a Chemical Engineer in a 30 MMSCFD natural gas processing plant in Bangladesh.
Bangladesh Chemical Industries Corporation (BCIC), Assistant Engineer, 2005 (full time). Responsible for maintaining safe operation of a urea processing plant.

5. Certifications or Professional Registrations

None

6. Current Membership in Professional Organizations

American Institute of Chemical Engineers (AIChE).
SPIE- the International Society for Optical Engineering.

7. Honors and Awards

Ceramographic Competition Award, Materials Science & Technology Conference and Exhibition, Pittsburgh, PA. 2012.

8. Service Activities

Departmental Service:
Member, Undergraduate Program Committee, 2016 - present.

9. Publications and Presentations

GK Das, DS Anderson, CD Wallis, SA Carratt, IM Kennedy, LS Van Winkle, Novel Multi-functional Europium-Doped Gadolinium Oxide Nanoparticle Aerosols Facilitate the Study of Deposition in the Developing Rat Lung, Nanoscale, 2016, 8 (22), 11518-11530.

GK Das, D Strak, IM Kennedy, Potential Toxicity of Up-Converting Nanoparticles Encapsulated with a Bilayer Formed by Ligand Attraction. Langmuir, 2014, 30, 8167-8176.

L Sudheendra, GK Das, C Li, D Stark, J Cena, SR Cherry, IM Kennedy, X-ray Luminescence from Europium-doped Lanthanide Fluoride Particles. Chemistry of Materials, 2014, 26, 1881–1888.

GK Das, CS Bonifacio, Rojasc, K Liu, Kv Benthem, IM Kennedy, Ultra-long Magnetic Nanochains for Highly Efficient Arsenic Removal from Water, Journal of Materials Chemistry A, 2014, 2, 12974-12981.

F Villarreal, GK Das, AD Abid, IM Kennedy, D Kültz, CuO Nanoparticles Caused Different Sublethal Effects in Mozambique Tilapia (Oreochromis mossambicus) Exposed to Different Salinities. PLoS One, 2014, 9, e88723.

GK Das, NJJ Johnson, J Cramen, B Blasiak, P Latta, B Tomanek, FCJM van Veggel $NaDyF_4$ Nanoparticles as T_2 Contrast Agents for Ultrahigh Field Magnetic Resonance Imaging. The Journal of Physical Chemistry Letters, 2012, 3, 524–529.

GK Das, Y Zhang, L D'Silva, JSC Loo, P Padmanabhan, BC Heng, JSC Loo, ST Selvan, KK Bhakoo, TTY Tan Single-Phase Dy_2O_3:Tb^{3+}Nanocrystals as Dual-Modal Contrast Agent for High Field Magnetic Resonance and Optical Imaging. Chemistry of Materials, 2011, 23, 2439–2446.

GK Das, DS Anderson, SA Carratt, C Wallis, IM Kennedy, LS Van Winkle Lanthanide Oxide Nanoparticle Aerosols Facilitate the Study of Deposition in the Developing Rat Lung, American Institute of Chemical Engineers (AIChE) Annual Meeting, Nov 2016, San Francisco, CA.

GK Das, IM Kennedy, Engineered Magnetic Nanochains for Highly Efficient Arsenic Removal from Water, American Institute of Chemical Engineers (AIChE) Annual Meeting, Nov 2014, Atlanta, GA.

GK Das, DS Anderson, SA Carratt, C Wallis, IM Kennedy, LS Van Winkle
Use of Novel Inhaled Metal Oxide Nanoparticles to Study Deposition in the Developing Respiratory System, Second Aerosol Dosimetry Conference, Oct 2014 Irvine, California.

GK Das, L Sudheendra, IM Kennedy, Heterogeneous Nanostructures for Plasmonic Interaction with Luminescence and Quantitative Surface-Enhanced Raman Spectroscopy, SPIE Photonics West 2014, Feb 2014, San Francisco, CA, USA.

GK Das, L Sudheendra, IM Kennedy, Lanthanide-doped Nanomaterials and Photonics for Environmental and Medical Research, International Conference on Materials for Advanced Technologies (ICMAT), July 2013, Singapore.

GK Das, TTY Tan, Gadolinium Oxide Ultranarrow Nanorods as Contrast Agent for Optical and Magnetic Resonance Imaging. 94th Canadian Chemistry Conference, Jun 2011, Montréal, Canada.

1. Name: **DOUGLAS D. FREY**

2. Education

Ph.D., Chemical Engineering, University of California, Berkeley, 1984.
M.S., Chemical Engineering, University of California, Berkeley, 1980.
B.S., Chemical Engineering, Stanford University, 1978.
B.A., Chemistry, Willamette University (combined degree program), 1978.

3. Academic Experience

UMBC, Professor, 2001-present (full time).
UMBC, Interim Department Chair, 1995-2000 (full time).
UMBC, Associate Professor, 1993-2001 (full time).
Yale, Associate Professor, 1990-3 (full time).
Yale, Assistant Professor, 1984-90 (full time).

4. Non-Academic Experience

W.R. Grace, Consultant, 1997-present (part time). Provided consulting services on projects related to the development of new materials.
NSF, Program Director, 2001-3, 2005 (part time). Directed the Separation Processes Program at the National Science Foundation.

5. Certifications or Professional Registrations

None

6. Current Membership in Professional Organizations

American Chemical Society
American Institute of Chemical Engineering

7. Honors and Awards

Henry Ford II Scholar Award (chosen by Stanford University faculty as the outstanding graduating senior from the School of Engineering), 1978.
Phi Beta Kappa, 1978.
Csaba Horvath Distinguished Lecturship in Chemical Engineering, Yale University, 2014.

8. Service Activities

Editorial Board Member, Biotechnology and Applied Biochemistr, 2004 - present.
Member, UMBC Professional Program Committee, 2012-present.
Member, UMBC Research Council, 2014-present.
ABET Coordinator, UMBC CBEE Dept., 1998-2000, 2016-7.
Undergraduate Adviser, UMBC CBEE Dept., 2015-present.
Graduate Program Director, UMBC CBEE Dept., 2005-2010.
Faculty Advisor for Toastmasters International Campus Chapter, UMBC, 2005-2010.
Undergraduate Program Director, UMBC CBEE Dept., 2004-7.

9. Publications and Presentations

N. D. S. Pinto, S. D. Uplekar, A. R. Moreira, G. Rao, and D. D. Frey, "Immunoglobulin G elution in Protein A chromatography employing the method of chromatofocusing for reducing the co-elution of impurities," Biotechnol. Bioeng. 114: 154-162, 2017.

G. Rao, Y. Kostov, L. Tolosa, L. Hung, X. Ge, D. D. Frey, and V. Singh, "Microscale bioprocessing system and method for protein manufacturing," US Patent 9,388,373, 2016.

M. M. El-Sayed and D. D. Frey "Chromatofocusing," in Encyclopedia of Life Sciences, Wiley, 2015.

N. D. S. Pinto and D. D. Frey, "Displacement chromatography of proteins using a retained pH front in a hydrophobic charge induction column," J. Chromatogr. A 1387: 53-59, 2015.

H. Guo, X. Li, and D. D. Frey, "Development of chromatofocusing techniques employing mixed mode column packings for protein separations," J. Chromatogr. A 1323: 57-65, 2014.

X. Kang, J. P. Kutzko, M. L. Hayes, and D. D. Frey, "Monoclonal antibody heterogeneity analysis and deamidation monitoring using high-performance cation-exchange chromatofocusing using simple, two component buffer systems," J. Chromatogr. A 1283: 89-97, 2013.

D. D. Frey, H. Guo, N. Karnik, "High-performance liquid chromatography in the undergraduate chemical engineering laboratory," Chem. Eng. Educ. 47: 15-24, 2013.

1. Name: **UPAL GHOSH**

2. Education

Ph.D., Civil and Environmental Engineering, State Univ. of New York, Buffalo, 1998.
M.S., Civil and Environmental Engineering, State Univ. of New York, Buffalo, 1993.
B. Tech., Chemical Engineering, Indian Institute of Technology, Bombay, 1989.

3. Academic Experience

UMBC, Professor, 2012-present (full time).
UMBC, Associate Professor, 2007-2012 (full time).
UMBC, Assistant Professor, 2002-2007 (full time).
Stanford University, Engineering Research Associate and Lecturer, 2000-2002 (full time).
Carnegie Mellon University, Post Doctoral Associate, 1999-2000 (full-time).

4. Non-Academic Experience

Sediment Solutions, President, 2009 – present (part time). Startup company established in 2009 specializing in in-situ sediment remediation: www.sedimite.com.
Indira Gandhi Institute of Development Research, Visiting Fellow, 1990 and 1992 (full time). Worked on research projects involving impacts of international trade on environment and demand-side management of electric power use.

5. Certifications or Professional Registrations

40 Hr. OSHA Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) Certification

6. Current Membership in Professional Organizations

American Chemical Society, Division of Environmental Chemistry
Water Environment Federation
Association of Environmental Engineering and Science Professors
Society for Environmental Toxicology and Chemistry
American Society of Civil Engineers

7. Honors and Awards

University of Maryland System Regents Award for Excellence in Research. 2016
Distinguished Service Award, Association of Environmental Engineering and Science Professors. 2015
Excellence in Environmental Engineering 2015 Honor Award for University Research, American Academy of Environmental Engineers and Scientists.
Visiting Professor, State Key Laboratory of Urban Water Resource and Environment, Harbin Institute of Technology, China, 2011-2014.
Best Poster Award, Gordon Research Conference, Environmental Sciences: Water, June 25-30, 2000.

8. Service Activities

Associate Editor, Environmental Toxicology and Chemistry journal (2015 - present)
Association of Environmental Engineering and Science Professors, Newsletter Editor (2011-2014)

USEPA Chesapeake Bay Program Toxics Committee member (2014-present)
Interstate Technology and Regulatory Council. Contaminated Sediments Team (2012).
Steering committee member and workgroup leader: SETAC Pellston Workshop on Passive Sampling Methods (2012)
Session Chair for several conferences
Reviewer for several journals
UMBC Interdisciplinary Life Science Building, Environmental Systems advisory committee (2015-2016)
UMBC Research Council (2015 Spring)
UMBC Graduate Program Director for Environmental Engineering (2005-2014)
CBEE faculty search committee co-chair (2010 and 2011 hires)

9. Publications and Presentations

M. Jalalizadeh, and U. Ghosh. "In situ passive sampling of sediment porewater enhanced by periodic vibration." Environ. Sci. Technol. 2016, 50, 8741–8749.
H. Xia, J.L. Gomez-Eyles, and U. Ghosh. "Effect of PAH source materials and soil components on partitioning and dermal uptake." Environ. Sci. Technol. 2016, 50, 3444–3452.
K. Sowers, B. Kjellerup, and U. Ghosh. "Organic biofilm substrata as a microbial inoculum delivery vehicle for bioaugmentation of persistent organic pollutants in contaminated sediments and soils." 2015, US Patent # 8,945,906.
H. Fadaei, A. Watson, A. Place, J. Connolly, U. Ghosh. "Measuring and modeling the effect of PCB bioavailability changes in sediments on bioaccumulation in fish." Environ. Sci. Technol. 2015, 49, 12405–12413.
M.V. Ruby, J.L. Gomez-Eyles, U. Ghosh, S.M. Roberts, P. Tomlinson, C.A. Menzie, J.C. Kissel, A.L. Bunge, Y.W. Lowney. "Oral bioavailability and dermal absorption of PAHs from soil – state of the science." Environ. Sci. Technol. 2016, 50, 2151–2164.
C. Patmont, U. Ghosh, et al. "In Situ Sediment Treatment Using Activated Carbon: A Demonstrated Sediment Cleanup Technology." Integr Environ Assess Manage. 2015, 11, 195-207.
N. J. Lombard, U. Ghosh, B. Kjellerup, K. Sowers. "Kinetics and threshold level of dechlorination activity by the anaerobic ultramicrobacterium Dehalobium Chlorocoercia DF-1." Environ. Sci. Technol. 2014, 48, 4353−4360.
B.V.V. Kjellerup, C. Naff, S.J. Edwards, U. Ghosh, J.E. Baker, K. Sowers. "Effects of activated carbon on reductive dechlorination of PCBs by halorespiring bacteria indigenous to sediments." Water Research. 2013, 52, 1-10.
C.C. Gilmour, G.S. Riedel, G. Riedel, S. Kwon, R. Landis, S.S. Brown, C.A. Menzie, E. A. Henry, and U. Ghosh. "Activated carbon mitigates mercury and methylmercury bioavailability in contaminated sediments." Environ. Sci. Technol. 2013, 47, 13001−13010.
P. Gidley, S. Kwon, A. Yakirevich, V. Magar, U. Ghosh. "Advection Dominated Transport of Polycyclic Aromatic Hydrocarbons in Amended Sediment Caps." Environ. Sci. Technol., 46, 5032-5039, 2012.
B. Beckingham, U. Ghosh. "Field scale reduction of PCB bioavailability with activated carbon amendment to river sediments." Environ. Sci. Technol., 2011, 45, 10567–10574.

1. Name: **CHRISTOPHER J. HENNIGAN**

2. Education
Ph.D., Environmental Engineering, Georgia Institute of Technology, 2008.
M.S., Environmental Engineering, Georgia Institute of Technology, 2006.
B.S., Chemistry, University of Florida, 2001.

3. Academic Experience
UMBC, Assistant Professor, 2012-present (full time).
Carnegie Mellon University, Postdoc, 2008-2012.

4. Non-Academic Experience
Westinghouse Savannah River Company, Analytical Chemist, 2001-2003 (full time). Uranium and plutonium isotopic analysis on mass spectrometer.

5. Certifications or Professional Registrations
None.

6. Current Membership in Professional Organizations
American Association for Aerosol Research.
American Geophysical Union.
Air and Waste Management Association.

7. Honors and Awards
NSF CAREER Award, 2015.

8. Service Activities
Member, UMBC Climate Action Committee, 2014-present.
UMBC SRAIS Review Committee, 2014-2015.
Newsletter Committee, American Association for Aerosol Research, 2014-2016.
Finance Committee Member, American Association for Aerosol Research, 2016-present.
Symposium Organizer, American Geophysical Union, fall 2013 meeting.

9. Publications and Presentations
El-Sayed, M. M. H.; Amenumey, D.; Hennigan, C. J., Drying-Induced Evaporation of Secondary Organic Aerosol during Summer, Environmental Science & Technology, 50 (7), 3626-3633 (2016).
Zhao, Y.; Nguyen, N. N.; Presto, A. A.; Hennigan, C. J.; May, A. A.; Robinson, A. L., Intermediate-Volatility Organic Compound Emissions from On-road Diesel Vehicles: Chemical Composition, Emission Factors and Estimated Secondary Organic Aerosol Production, Environmental Science & Technology, 49 (19), 11516-11526 (2015).
El-Sayed, M. M. H.; Wang, Y.; Hennigan, C. J., Direct atmospheric evidence for the irreversible formation of aqueous secondary organic aerosol (aqSOA), Geophysical Research Letters, doi:10.1002/2015GL064556 (2015).

Hennigan, C. J.; Izumi, J.; Sullivan, A. P.; Weber, R. J.; Nenes, A., A critical evaluation of proxy methods used to estimate the acidity of atmospheric particles, Atmospheric Chemistry and Physics, 15, 2775-2790 (2015).

Zhao, Y.; Hennigan, C. J.; May, A. A.; Tkacik, D. S.; de Gouw, J. A.; Gilman, J.; Kuster, W. C.; Borbon, A.; Robinson, A. L., Intermediate-volatility organic compounds: a large source of secondary organic aerosol, Environmental Science & Technology, 48 (23), 13743-13750 (2014).

Jathar, S. H.; Gordon, T. D.; Hennigan, C. J.; Pye, H. O. T.; Pouliot, G.; Adams, P. J.; Donahue, N. M.; Robinson, A. L., Unspeciated organic emissions from combustion sources and their influence on the secondary organic aerosol budget in the United States, Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1323740111 (2014).

May, A. A.; Presto, A. P.; Hennigan, C. J.; Nguyen, N. T.; Gordon, T. D.; Robinson, A. L., Gas-particle partitioning of primary organic aerosol emissions: (2) Diesel vehicles, Environmental Science & Technology, 47, 8288-8296 (2013).

May, A. A.; Presto, A. P.; Hennigan, C. J.; Nguyen, N. T.; Gordon, T. D.; Robinson, A. L., Gas-particle partitioning of primary organic aerosol emissions: (1) Gasoline vehicle exhaust, Atmospheric Environment, doi: 10.1016/j.atmosenv.2013.04.060. (2013).

Saleh, R.; Hennigan, C. J.; McMeeking, G. R.; Chuang, W. K.; Robinson, E. S.; Coe, H.; Donahue, N. M.; Robinson, A. L., Absorptivity of brown carbon in fresh and photochemically aged biomass burning emissions, Atmospheric Chemistry and Physics, 13, 7683-7693 (2013).

May, A. A.; Saleh, R.; Hennigan, C. J.; Donahue, N. M.; Robinson, A. L., Volatility of Organic Molecular Markers Used for Source Apportionment Analysis: Measurements and Implications for Atmospheric Lifetime, Environmental Science & Technology, 46, 12435-12444 (2012).

Presto, A. A.; Hennigan, C. J.; Nguyen, N. T.; Robinson, A. L., Determination of Volatility Distributions of Primary Organic Aerosol Emissions from Internal Combustion Engines using Thermal Desorption Gas Chromatography Mass Spectrometry, Aerosol Science and Technology, 46, 1129-1139 (2012).

Hennigan, C. J.; Westervelt, D. M.; Riipinen, I.; Engelhart, G. J.; Lee, T.; Collett, J. L.; Pandis, S. N.; Adams, P. J., Robinson, A. L., New particle formation and growth in biomass burning plumes: an important source of cloud condensation nuclei, Geophysical Research Letters, 39, L09805, doi:10.1029/2012GL050930 (2012).

1. Name: **ERIN LAVIK**

2. Education

Sc.D., Materials Sci.& Eng. (Polymers), MIT 2001
S.M., Materials Sci.& Eng., MIT, 1997
S.B., Materials Sci.& Eng., MIT, 1995

3. Academic Experience

UMBC, Professor, 2016-present (full time).
Case Western Reserve University, Professor, 2015-2016 (full time).
Case Western Reserve University, Associate Professor, 2009-2015 (full time).
Yale University, Associate Professor, 2008-2009 (full time).
Yale University, Assistant Professor, 2003-2008 (full time).

4. Non-Academic Experience

Associate Editor, Bioconjugate Chemistry, an ACS Journal 2014-present.

5. Certifications or Professional Registrations

None.

6. Current Membership in Professional Organizations

American Chemical Society
American Institute of Chemical Engineers
American Institute for Medical and Biological Engineers

7. Honors and Awards

Fellow, American Institute of Medical and Biological Engineers (AIMBE), 2014
Editorial Advisory Board, Macromolecules and ACS Macro Letters, 2013
Flora Stone Mather Award, Case Western, 2011
Research Award, Case School of Engineering, 2011
Director's New Innovator Award, NIH, 2010
Seton Elm-Ivy Award, Yale University, 2009
Poorvu Family Award for Interdisciplinary Teaching, Yale University, 2008
Academic Leadership and Innovation Award, Connecticut Technology Council, 2008

8. Service Activities

Graduate Program Director, CBEE 2016-present
Graduate Admissions Committee, CBEE 2016-present
College of Engineering and Information Technology Liaison to University of Maryland, Baltimore, 2016-present
HHMI International Postdoctoral Grant Application Review, March 2013, 2016.
Editorial Advisory Board, Stem Cells Reviews and Reports, 2009-present.
NSF Merit Review Panel 2016.
NIH Ad hoc reviewer,

Nanomaterials Health Implications Research (NHIR): Engineered Nanomaterials Resource and Coordination Core (U24), February, 2016.

Standing Member of Gene and Drug Delivery (GDD) Study Section, 2014-2020.

NIH ad hoc reviewer Fellowship Review: Cell Biology, Developmental Biology, and Bioengineering [F05], November 2013.

Guest editor for Special Issue on Bioengineering in Neuroscience Letters, 2011-2

9. Publications and Presentations

Lavik, E., Kuehn, M. H., Shoffstall, A., Atkins, K., Dumitrescu, A. V. and Kwon, Y. H., Sustained Delivery of Timolol Maleate for over 90 days via Subconjunctival Injection. Journal of Ocular Pharmacology and Therapeutics. accepted.

Lashof-Sullivan, M., Holland, M., Groynom, R., Campbell, D., Soffstall, A. and Lavik, E. B., Hemostatic Nanoparticles Improve Survival Following Blunt Trauma Even after 1 Week Incubation at 50 degrees C. ACS Biomaterials Science & Engineering. 2016.

Szeto, G. L. and Lavik, E., Materials design at the interface of nanoparticles and innate immunity. Journal of Materials Chemistry B. 2016.

van Hest, J., Lavik, E. B., Smith, B. D., Zheng, G. and Rotello, V., Editorial. Bioconjug Chem, 27(1): p. 1-2. 2016.

R. Groynom, L. Wu, E. Shoffstall, and E.B. Lavik. Controlled release of photoswitch drugs by PLGA microsphere encapsulation, Journal of Drug Targeting, 4(4): p. 387-391. 2015.
Hubbard, WB, Lashof-Sullivan, M, Sajja, VS, Lavik, E, and VandeVord, P. Addition of Dexamethasone to Hemostatic Nanoparticles Combats Pulmonary Hemorrhaging after Primary Blast Lung Injury, ACS Macro Letters, 4(4): p. 387-391. 2015.

Tsuneki, M., Hardee, S., Michaud, M., Morotti, R., Lavik, E., Madri, J. A Hydrogel-Endothelial Cell implant Mimics Infantile Hemangioma: Modulation by Survivin and the Hippo pathway, Laboratory Investigation, 4(4): p. 387-391. 2015.

van Hest, J., Lavik, E. B., Smith, B. D., Zheng, G. and Rotello, V., Editorial. Bioconjug Chem. 2015.

Sethi, R., Sethi, R., Redmond, A. and Lavik, E. B., Olfactory Ensheathing Cells Promote Differentiation of Neural Stem Cells and Robust Neurite Extension, Stem Cells Reviews and Reports, in press.

Lashof-Sullivan, Shoffstall, E., Atkins, K., Keane, N., Bir, C., VandeVord, P., Lavik, E. Intravenously Administered Nanoparticles Increase Survival Following Blast Trauma. Proceedings of the National Academy of Sciences, 111 (28): p. 10293-10298.
Hubbard, WB, Hall, C, Sajja, VS, Lavik, E, and VandeVord, P. Examining lethality risk for rodent studies of primary blast lung injury. Biomed Sci Instrum. 2014.

Lashof-Sullivan, M., Shoffstall, A. and Lavik, E., Intravenous hemostats: challenges in translation to patients. Nanoscale, 5(22): p. 10719-28. 2013.

Shoffstall, A. J., Everhart, L. M., Varley, M. E., Soehnlen, E. S., Shick, A. M., Ustin, J. S. and Lavik, E. B., Tuning Ligand Density on Intravenous Hemostatic Nanoparticles Dramatically Increases Survival Following Blunt Trauma. Biomacromolecules. 2013.

1. Name: **JENNIE B. LEACH**

2. Education
Ph.D., Chemical Engineering, University of Texas, Austin, 2003.
B.S., Chemical Engineering, Rensselaer Polytechnic Institute, 1998.

3. Academic Experience
UMBC, Associate Professor, 2011-present (full time).
University of Maryland, Baltimore, School of Medicine, Assistant/Associate Professor, 2006-present (by courtesy)
UMBC, Clare Boothe Luce Assistant Professor, 2005-2011 (full time).

4. Non-Academic Experience
None

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
Biomedical Engineering Society
Society for Biomaterials

7. Honors and Awards
Selected as one of the Top 10 Reviewers for Integrative Biology, 2016
Selected for UMBC "On-Ramps to Full Professor" Program, 2015
Selected for UMBC ADVANCE Leadership 2014 Cohort, 2014
Clare Boothe Luce Professorship, 2005-2011

8. Service Activities
Departmental Service:
Mentor for Junior Faculty (Lee Blaney and Gregory Szeto), 2012-present
Chair, Search Committee for three tenure-track positions, 2013-2015.
Member, Search Committee for Department Chair, 2013.
Member, Post-Tenure Review Committee, 2012-present.
Co-Chair, Search Committee for four faculty positions, 2010-2012.
Undergraduate Academic Advisor for 50-60 students, 2007-present.
Member, Undergraduate Program Committee, 2007-present.

University Service:
Team Leader, Interdisciplinary Life Science Building (ILSB) Facility Capital Equipment Request Committee, 2015-2016.
Member, Search Committee for Dean of the College of Engineering and Information Technology, 2013-2014.
Member, Steering Committee, MARC U-STAR Program at UMBC, 2013-2015.
Vice-Chair, Faculty Steering Committee, Keith R. Porter Core Imaging Facility, 2013-present.
Member, Research Misconduct Investigation Committee, 2013-2014.

Member, UMBC Goldwater Scholarship Selection Committee, 2012-2015.
Member, Undergraduate Research Award (URA) Selection Committee, 2011-2015.

Professional Service:
Study Section Member, NIH Bioengineering of Neuroscience, Vision and Low Vision Technologies, 2016-2020.
Scientific Advisory Committee, Tissue Engineering and Regenerative Medicine International Society Americas (TERMIS-AM), 2013-2014.
Director, American Institute of Chemical Engineers (AIChE), Area 8b Materials Engineering and Sciences Division (MESD), 2010-2011.
Executive Committee, AIChE, Area 8b MESD, 2009-2012

9. Publications and Presentations

Balasubramanian S, JA Packard, JB Leach, EM Powell. (2016) Three-dimensional environment sustains morphological heterogeneity and promotes phenotypic progression during astrocyte development. Tissue Engineering 22:885-898.

Ghourichaee SS, JB Leach. (2016) Synergistic effects of substrate and hypoxia on human neural stem cell proliferation. Journal of Materials Chemistry B 4:3509-3514.

Leach JB, MS Shoichet. (2015) Naturally-derived and bioinspired materials. Journal of Materials Chemistry B. 3:7814-7.

Balasubramanian S, EM Powell, JB Leach. (2015) Culturing Neurons, Glia and Progenitor Cells in 3D Hydrogels. Neuromethods: Extracellular Matrix, Eds: JB Leach and E Powell, Springer Protocols, Humana Press, 93: 91-99.

Balasubramanian S, EM Powell, JB Leach. (2015) Investigating Cell-ECM Interactions and ECM Synthesis in 3D Hydrogels. Neuromethods: Extracellular Matrix, Eds: JB Leach and E Powell, Springer Protocols, Humana Press, 93: 101-109.

Ribeiro A, S Balasubramanian, D Hughes, S Vargo, E Powell, JB Leach. (2013) β1-integrin Cytoskeletal Signaling Regulates Sensory Neuron Response to Matrix Dimensionality. Neuroscience 248:67-78.

Zustiak SP, S Pubill, A Ribeiro, JB Leach. (2013) Hydrolytically degradable poly(ethylene glycol) hydrogel scaffolds as a cell delivery vehicle: Characterization of PC12 cell response. Biotechnology Progress 29:1255-64.

Wang L, MA Acosta, JB Leach, R Carrier. (2013) Spatially monitoring oxygen level in 3D microfabricated cell culture systems using optical oxygen sensing beads. Lab on a Chip 13:1586-92.

Zustiak SP, Y Wei, JB Leach. (2013) Protein-Hydrogel Interactions in Tissue Engineering: Mechanisms and Applications. Tissue Eng B: Reviews 19:160-71.

Acosta MA, M Velasquez, K Williams, JM Ross, JB Leach. (2012) Fluorescent silica particles for monitoring oxygen levels in three-dimensional heterogeneous cellular structures. Biotechnology & Bioengineering 106:2663-70.

Ribeiro A, S Vargo, E Powell, JB Leach. (2012) Substrate three-dimensionality induces elemental morphological transformation of sensory neurons on a physiologic timescale. Tissue Engineering 18:93-102.

Zustiak S, JB Leach. (2011) Characterization of protein release from hydrolytically degradable poly(ethylene glycol) hydrogels. Biotechnology & Bioengineering 108:197-206.

1. Name: **MARK R. MARTEN**

2. Education

Ph.D., Chemical Engineering, Purdue U., W. Lafayette, IN, 1991.
M.S., Chemical Engineering, Purdue U., W. Lafayette, IN, 1988.
B.S., Chemical Engineering, SUNY Buffalo, NY, 1978.

3. Academic Experience

UMBC, Interim Department Chair, 2016-present (full time).
UMBC, Professor, 2008-present (full time).
UMBC, Associate Professor, 2003-2008 (full time).
UMBC, Assistant Professor, 1996-2003 (full time).
NC State, Postdoc, Chemical Engineering, 1993-1994 (full time).

4. Non-Academic Experience

MycoInnovation, LLC, 2012-present (part time). Founder and Chief Executive Officer.
Novozymes, 1994-1996 (full time). Postdoctoral Research Associate.
New Life Soviet Union, 1991-1992 (full time). Lecturer, Vilnius University, Lithuania.

5. Certifications or Professional Registrations

None

6. Current Membership in Professional Organizations

American Chemical Society (ACS)
American Institute of Chemical Engineering (AIChE)
Genetics Society of America (GSA)

7. Honors and Awards

Finalist, Maryland Incubator Company of the Year (MycoInnovation, LLC), 2014.
American Chemical Society Division of Biochemical Technology James M. Van Lanen Distinguished Service Award, 2009.
Univ. System of Maryland Regents Award for Research Collaboration, 2007.
National Science Foundation CAREER Award, 1999.
Dow Award for Outstanding Teaching Assistant, 1990.
Edwin Sokol Scholarship for outstanding chemical engineering student, 1985.

8. Service Activities

Associate Editor Biotechnology & Bioengineering, 2011-present.
Faculty Advisor, Circus Arts Club, UMBC, 2014-present.
Faculty Advisor, Cru, UMBC, 2010-present.
Library Liaison, UMBC CBEE Dept., 1999-2016.
Long Range Program Coordinator, ACS, BIOT, 2006-2014.
Chair, Faculty Search Committee, UMBC CBEE Dept., 2015-2016.
Member, Faculty Search Committee, UMBC CBEE Dept., 2011-2015.
Member, COEIT, Dean Search Committee, UMBC, 2014.

Chair, CENG Graduate Program Admissions Comm., UMBC CBEE Dept., 2010-2014.
Member, ACS BIOT Division Executive Comm, 2003-2013.
Member, Undergraduate Research Award (URA) Committee, UMBC, 2012-2013.
Faculty mentor for Jennie Leach, UMBC CBEE Dept., 2007-2011.
Member, Microscopy Committee, UMBC, 2011.
Editorial Board Biotechnology & Bioengineering, 2007-2011.
Member, Mass Spectrometry Committee, UMBC, 2003-2010.
Web Coordinator, UMBC CBEE Dept., 1996-2015.
Chair, P&T Committee Jennie Leach, UMBC CBEE Dept., 2010.
ABET Coordinator, UMBC CBEE Dept., 2003-2008.
Chair, COEIT Web Presence Task Force, 2007-2008.
Member, Master Professional Studies (MPS) Biotechnology Committee, 2006-2007.
Member, Faculty Search Comm., UMBC CBEE Dept., 2000-2004.
Member, COEIT Dean Search Committee, 2006.
Chair, Graduate Recruiting and Admissions Comm. UMBC CBEE Dept., 1996-2002.
Program Chair, ACS BIOT Division, 2003.
Seminar Coordinator, UMBC CBEE Dept., 1996,2001-2003.
Program Chair, AIChE Area 15c, 2000.
Program Vice Chair, AIChE Area 15c, 1999.

9. Publications

Nazrul Islam, Julia M. Ross and Mark R. Marten, "Proteome analyses of Staphylococcus aureus biofilm at elevated levels of NaCl." Clinical Microbiology, 4:219-222, 2015.

Ramsubramaniam, Nikhil; Harris, Steven D.; and Marten, Mark R., "The phosphoproteome of Aspergillus nidulans reveals functional association with cellular processes involved in morphology and secretion." Proteomics, 14:2454–2459, 2014.

Nazrul Islam, Yonghyun Kim, Julia M. Ross and Mark R. Marten, "Proteomic analysis of Staphylococcus aureus biofilm cells grown under physiologically relevant fluid shear stress conditions." Proteome Science, 12:21, 2014.

Ramsubramaniam, Nikhil; Tao, Feng; Li, Shuwei; Marten, Mark R., "Cost effective isobaric tagging for quantitative phosphoproteomics using DiART reagents." Molecular BioSystems, 9:2981-2987, 2013.

Ramsubramaniam, Nikhil; Tao, Feng; Li, Shuwei; Marten, Mark R., "Novel and cost effective 6-plex isobaric tagging reagent, DiART is effective for identification and relative quantification of complex protein mixtures using PQD fragmentation." J. Mass Spectrometry, 48:1032-1041, 2013.

D.J. Klionsky et al., "Guidelines for the use and interpretation of assays for monitoring autophagy." Autophagy. 8: 445-544, 2012.

Y. Kim, N. Islam, B.J. Moss, M.P. Nandakumar, M.R. Marten, "Autophagy induced by rapamycin and carbon-starvation have distinct proteome profiles in Aspergillus nidulans," Biotechnology Bioengineering, 108:2705-2715, 2011.

1. Name: ANTONIO R. MOREIRA

2. Education
Ph.D., Chemical & Biochemical Engineering, University of Pennsylvania, 1977.
M.S., Chemical & Biochemical Engineering, University of Pennsylvania, 1975.
B.S., Chemical Engineering, University of Oporto, Portugal, 1973.

3. Academic Experience
UMBC, Vice Provost for Academic Affairs, 1997-Present (full-time)
UMBC, Associate Provost for Academic Affairs, 1995-1997 (full-time)
UMBC, Associate Dean of Engineering, 1995 (full-time)
UMBC, Chair and Professor, Department of Chemical and Biochemical Engineering, 1992-1995 (full-time)
University of Maryland Biotechnology Institute, Acting Co-Director, Center for Biotechnology Manufacturing, 1990-1993 (part-time)
UMBC, Director and Professor, Chemical and Biochemical Engineering Program, 1990-1992 (full-time)
UMBC, Professor, Chemical, Biochemical and Environmental Engineering Department, 1990-present
Colorado State University, Faculty Affiliate, Department of Agricultural and Chemical Engineering, 1983-1985 (part-time)
Colorado State University, Associate Professor (with tenure), Department of Agricultural and Chemical Engineering, 1982 (full-time)
Colorado State University, Assistant Professor, Department of Agricultural and Chemical Engineering, 1978-1982 (full-time)
Post-Doc, Biochemical Engineering, University of Waterloo, Canada, 1977.

4. Non-Academic Experience
None

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
American Chemical Society (and BIOT Division), 1975-Present
American Institute of Chemical Engineers (and FPBE Division), 1975-Present
International Society for Pharmaceutical Engineering, 1994-Present
Parenteral Drug Association, 1995-Present
American Society for Engineering Education, 2002-Present
Society for Biological Engineering, 2005-Present

7. Honors and Awards
Temporary Voting Member, Food and Drug Administration, Arthritis Advisory Committee, 2016
Temporary Voting Member, Food and Drug Administration Oncologic Drug Advisory Committee, 2015

National Order of Merit for Public Education with the title of Comendador awarded by the President of the Republic of Portugal, 2014
Special Government Employee, Food and Drug Administration, 2014-2018

8. Service Activities (Selected list)
Chair, UMBC Course Evaluation Implementation Committee, 2013-present Co-Chair, Quality Risk Management Summit, Lisbon, Portugal, May 10-11, 2017
Co-Chair, ECI on Regulatory Sciences for Biologics and Vaccines: Accelerating Development and Enabling Manufacturing Innovation, Leesburg, VA, April 23-26, 2017
Editor, Comprehensive Biotechnology, 3rd Edition, Volume 3 on Industrial Biotechnology and Commodity Products, Elsevier Publishing Co., 2017-2019
Member, International Board of Directors of the International Society for Pharmaceutical Engineering, 2015-2017
Director, International Workshop on "Biotechnology: Challenges and Opportunities", invited by SINDUSFARMA, São Paulo, Brazil, 2013
Member, UMBC Space Management Committee, 2013-present
Editor, Comprehensive Biotechnology. 2nd Edition. Volume 3 on Industrial Biotechnology and Commodity Products. Elsevier Publishing Co., 2008-2011
Chair, UMBC IT Steering Committee, 2004-present
Chair, UMBC Classroom Committee, 2004-present
Member, UMBC President's Council, 1997-present
Member, UMBC Council of Deans, 1997-present

9. Publications and Presentations (Selected from close to 200 publications and presentations)
Nacole D. Lee, Bhargavi Kondragunta, Shaunak D. Uplekar, Jose Vallejos, Antonio R. Moreira, Govind Rao. 2015. Studies of Protein Oxidation as a Product Quality Attribute in a Scale-Down Model for Cell Culture Process Development. PDA Journal of Science and Technology, Volume 69(2), March/April, p. 236-247.
J. R. Vallejos, M. Micheletti, K. A.Brorson, A. R. Moreira, and G. Rao. 2012. Optical sensor enabled rocking T-flasks as novel upstream bioprocessing tools. Biotechnology and Bioengineering, Volume 109, Issue 9, p. 2295-2305.
J. R. Vallejos, S. Uplekar, J. F. da Silva, K. A. Brorson, A. R. Moreira, and G. Rao. 2012. A case study in converting disposable process scouting devices into disposable bioreactors as a future bioprocessing tool. Biotechnology and Bioengineering, Volume 109, Issue 11, p. 2790-2797.
B. Kondragunta, B. H. Joshi, J. Han, K. A. Brorson, R. K. Puri, A. R. Moreira, and G. Rao. 2012. Bioreactor environment-sensitive sentinel genes as novel metrics for cell culture scale comparability. Biotechnology Progress, Volume 28 (5), September/October, p. 1138-1151.
B. Kondragunta, B. H. Joshi, J. Han, K. A. Brorson, R. K. Puri, A. R. Moreira, and G. Rao. 2012. Genomic analysis of batch cell culture metabolic status in a standard laboratory 5L bioreactor. Biotechnology Progress, Volume 28 (5), September/October, p. 1126-1137.
J. Vallejos, K. Brorson, A. Moreira, G. Rao. 2011. Integrating a 250 mL-spinner flask with other stirred bench-scale cell culture devices: A mass transfer perspective. Biotechnology Progress, Volume 27, Issue #3, p. 803-810.

1. Name: **NEHA B. RAIKAR**

2. Education
Ph.D., Chemical Engineering, University of Massachusetts, Amherst, 2010.
Bachelor in Chemical Engineering, University Institute of Chemical Technology, Mumbai, India, 2004.

3. Academic Experience
UMBC, Lecturer, Fall 2016-present (full time).
UMBC, Lecturer, Fall 2014-Summer 2016 (part time).

4. Non-Academic Experience
Unilever Research, Vlaardingen, The Netherlands, 2010-2014 (full time). Support the designing of consumer products and the manufacturing process as well as improving existing operations.

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
None

7. Honors and Awards
Unilever Research & Development Author Award 2010
John Eldridge Award 2006

8. Service Activities
Member, Undergraduate Committee, 2016-present.
Member, Workload Committee, 2016-present.

9. Publications and Presentations
M.A.H. van Elzakker., E. Zondervan, N.B. Raikar, H. Hoogland, and I.E. Grossman, "An SKU Decomposition Algorithm for the Tactical Planning in the FMCG Industry", Computers and Chemical Engineering, 62, 8095 (2014).
Elzakker M.A.H, Zondervan, Raikar N.B., Grossmann I.E., and Bongers P.M.M., "Scheduling in the FMCG industry: An Industrial Case Study", Industrial & Engineering Chemistry Research, 51(22), 7800-7815 (2012).
Maindarkar, S.N.; Raikar, N.B.; Bongers, P., and Henson, M.A, "Incorporating emulsion drop coalescence into population balance equation models of high pressure homogenization", Colloids and Interfaces A: Physicochemical and Engineering Aspects, 396, 63-73 (2012).
Raikar N.B., Bhatia S.R., Malone M.F., and Henson M.A.,"Predicting the Effect of the Homogenization Pressure on Emulsion Drop-Size Distributions", Industrial & Engineering Chemistry Research, 50(10), 6089-6100 (2011).

1. Name: **GOVIND RAO**

2. Education
BS, Chemical Engineering, IIT (Madras), 1984
PhD, Chemical Engineering, Drexel University, 1987

3. Academic Experience

Visiting Assistant Professor Chemical and Biochemical Engineering Program, UMBC	(1987 – 1988)
Assistant Professor Medical Biotechnology Center (51%) and Department of Chemical and Biochemical Engineering, UMBC (49%)	(1988 – 1992)
Associate Professor Medical Biotechnology Center (51%) and Department of Chemical and Biochemical Engineering, UMBC (49%) (Promoted to Professor effective 7/1/96)	(1992 – 1996)
Professor Medical Biotechnology Center (51%) and Department of Chemical and Biochemical Engineering, UMBC (49%)	(1996 – 2000)
Professor and Chair Department of Chemical and Biochemical Engineering, UMBC	(2000 – 2006)
Professor and Director Center for Advanced Sensor Technology, UMBC	(2006 –)

4. Non-Academic Experience
Developed a cell culture bioreactor as consultant for Artisan Industries, Inc.
Co-founder of Fluorometrix, Inc.
Consultant for FluorRx and SpectrRx Inc. for Lifetime-Based Sensors
Consultant to Sartorius-Stedim Biotechnology

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
American Chemical Society, Division of Biochemical Technology
Parenteral Drug Association

7. Honors and Awards

National Talent Scholar, Government of India.	(1977-84)
Outstanding Teaching Award, UMBC College of Engineering.	(1989)
Outstanding Research Award, UMBC College of Engineering.	(1991)
Presidential Young Investigator, National Science Foundation.	(1991)
Citation from the Literacy Volunteers of America.	(1991)
Visiting Professor, Facultes Universitaires Notre-Dame De La Paix, Namur, Belgium.	(1992-93)
Chair, Division of Biochemical Technology (BIOT), American Chemical Society.	(1998)

Elected Fellow, American Institute for Medical and Biological Engineering. (1999)
Van Lanen Award for Distinguished Service, BIOT, American Chemical Society. (2000)
Gaden Award for Most Influential Paper published in Biotechnol. Bioeng. in 2001. (2002)
University System of Maryland Regents' Faculty Award for Excellence in Research. (2003)
Named 2003 Innovator of the Year Finalist by the Maryland Daily Record. (2003)
FDA Leveraging/Collaboration Award for Optical Sensor-based Parallel Bioreactor (2007)
Elected Fellow of the American Association for the Advancement of Science (2007)
Bright ideas award for >50 inventions UMBC (2015)
Eminent Engineer, Tau Beta Pi (2015)

8. Service Activities

Chair, Department of Chemical & Biochemical Engineering (2000-2006)
Director, Center for Advanced Sensor Technology (2006-present)
Ad hoc Reviewer and Panel Member for the National Science Foundation and Study Section Member for National Institutes of Health.
Editorial board member for Journal of Industrial Microbiology and Biotechnology, Biotechnology Letters; Biotechnology and Bioengineering,
Reviewer for Biotechnology and Bioengineering, Biotechnology Progress, Applied Microbiology and Biotechnology, Enzyme and Microbial Technology, Journal of Fluorescence, Nature Medicine, Analytical Chemistry, Applied Spectroscopy, Analyst, Journal of Biomedical Optics, AIChE Journal and Chemical Engineering Science.
Associate Editor- Biotechnology & Bioengineering
Editor- PDA Journal of Pharmaceutical Science and Technology.

9. Publications and Presentations

NDS Pinto, SD Uplekar, AR Moreira, G Rao, DD Frey, Immunoglobulin G elution in protein A chromatography employing the method of chromatofocusing for reducing the co-elution of impurities, Biotechnology and Bioengineering, 114 (1), pg 154-162, January, 2017.
AS Vishwanathan, KS Aiyer, LAA Chunduri, K Venkataramaniah, SSS Sai, and G. Rao, Carbon quantum dots shuttle electrons to the anode of a microbial fuel cell, 3 Biotech 6 (2), 228, Dec 2016
N Sardesai, M Al-Adhami, G Rao, Y Kostov, Modelling and implementation of a fixed-length-extension to measure fluorescent intensity in bioprocesses using an optical sensor Smart Biomedical and Physiological Sensor Technology XIII, 98630J, 13 May 2016; doi: 10.1117/12.2221931
G Rao, Y Kostov, L Tolosa, X Ge, D Frey, System and method for production of on-demand proteins in a portable unit for point of care delivery, US Patent App. 2016/0222341, Aug 4, 2016.
M Al-Adhami, D Tilahun, G Rao, Y Kostov, Optical sensor for rapid microbial detection, Proc. SPIE9862, Advanced Environmental, Chemical and Biological Sensing, April 2016.

1. Name: **BRIAN E. REED**

2. Education

Ph.D., Civil Engineering, State University of New York at Buffalo, 1990
MS, Civil Engineering, State University of New York at Buffalo, 1986
BS, Civil Engineering, State University of New York at Buffalo, 1984

3. Academic Experience

UMBC, Professor, 2016-present (full time).
UMBC, Professor and Chair, 2013-2016 (full time).
UMBC, Professor, 2002-2013 (full time).
University of Missouri, Associate Professor, 2000-2002 (full time).
West Virginia University, Associate Professor, 1995-2000 (full time).
West Virginia University, Assistant Professor, 1991-1995 (full time).
Texas A&M University-Kingsville, Assistant Professor, 1990-1991 (full time).

4. Non-Academic Experience

NA

5. Certifications or Professional Registrations

NA

6. Current Membership in Organizations

Association of Environmental Engineering and Science Professors

7. Honors and Awards

Fulbright Scholarship 2011-12

8. Service Activities

NA

9. Publications and Presentations

Ngantcha-Kwimi, T.A., and Reed, B.E. (2015). "As(V) and PO4 Removal by an Iron Impregnated Activated Carbon in a Single and Binary Adsorbate system: Experimental and Surface Complex Modeling Results." ASCE Journal of Environmental Engineering 142 (1).

Ngantcha, T.A., Vaughan, R., and Reed, B.E. (2011). "Modeling As(III) and As(V) Removal by an Iron Oxide Impregnated Activated Carbon in a Binary Adsorbate System." Separation Science and Technology 46, 1419-1429.

Vaughan, Jr., R.L., Reed, B.E., and Smith, E.H, "Modeling As(V) Removal in Iron Oxide Impregnated Activated Carbon Columns." ASCE Journal of Environmental Engineering, 133, 1, 121-124., 2007

Vaughan, Jr., R.L., and Reed, B.E. "Modeling As(V) Removal by an Iron Oxide Impregnated Activated Carbon using the Surface Complexation Approach," Water Research, V39, 1005-1014, 2005.

Vaughan, R.L.,Yang, J., Lemire, L., and Reed, B.E, “Characterization and Surface Acidity Modeling of an Iron Oxide Impregnated Activated Carbon,” Adsorption Science and Technology, 25(5), 295-309, 2007

1. Name: **JOHN ALLEN RUDESILL**

2. Education
BS, Chemical Engineering, California State University Pomona, California, 1972.

3. Academic Experience
UMBC, Instructor, 2007-present (part time).

4. Non-Academic Experience
Energy Technology Consultant, 2005-present (part time). Completed engineering design and economic analysis for multiple clients. Served as expert witness.
Grace Refining Catalysts, Principal Engineer, 1973-2004 (full time). Did process engineering in manufacturing, process development, and research for Fluid Cracking Catalyst product line. Co-inventor 21 US Patents

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
American Association for the Advancement of Science.
American Chemical Society
American Institute of Chemical Engineers.
International Council on Systems Engineering

7. Honors and Awards
None

8. Service Activities
Member & co-founder Future of Energy Initiative working group, 2012 to present.
Advisor to Interfaith Center environmental "Green Teams", 2008 to present.

9. Publications and Presentations
N. Goudarzi, A. Pavlak, J. Rudesill, "ASME Power Energy: Cost Performance Tradeoff Study of Wind Systems: Grid-Scale Storage," Energy-Tech e-newsletter, October 4, 2016 .
A. Pavlak, H, Winsor, J. Rudesill, "Is It Safe to Live Near Nuclear Power?," The Hill-- Congress Blog, Washington DC, USA, March 2, 2016.
J. Rudesill, "Systems Engineering Approach to Zero Carbon Emission Grid: Variable Generators, Storage, Back-Up, Electricity Cost Trends," presentation at Argon Power Cycle Workshop, University of California, Berkeley, August 2, 2014

1. Name: **GREGORY SZETO**

2. Education
Ph.D., Cellular & Molecular Medicine, Johns Hopkins University School of Medicine, 2010.
B.S., Chemical Engineering, Biomedical & Health Engineering, Carnegie Mellon University, 2004.

3. Academic Experience
UMBC, Assistant Professor, 2016-present (full time).
MIT, Postdoctoral Fellow, 2011-2015 (full time).

4. Non-Academic Experience
None

5. Certifications or Professional Registrations
None

6. Current Membership in Professional Organizations
American Association of Immunologists
American Association for Cancer Research
American Institute for Chemical Engineers
Biomedical Engineering Society

7. Honors and Awards
Research Fellow, Multiple Myeloma Research Foundation, 2016.
Distinguished Alumni, Johns Hopkins University School of Medicine Cellular & Molecular Medicine Program, 2016.
Institutional Nominee (UMBC), Searle Scholars, 2016.
Koch Institute Herman Eisen Travel Fellowship, 2015.
Winner, Wellcome Image Awards, 2015.
Winner, Koch Institute Image Awards & Public Galleries, 2015.
Finalist, A*STAR Investigatorship, 2014.
NIH NCI F32 Ruth L. Kirschstein National Research Service Awards (NRSA) Postdoctoral Fellowship, 2013.
Ragon Institute Postdoctoral Fellowship, Systems Biology, 2011.

8. Service Activities
Cochair, Gordon Research Seminar on Immunochemistry & Immunobiology, 2016.

9. Publications and Presentations
Moynihan KD, Opel CF, Szeto GL, Tzeng A, Zhu EF, Engreitz JM, Williams RT, Rakhra K, Zhang MH, Rothschilds AM, Kwan BH, Abraham W, Hu K, Kauke MJ, Suh H, Lauffenburger DA, Wittrup KD, Irvine DJ. "Eradication of large established tumors by combination immunotherapy engaging innate and adaptive immunity." Nature Medicine, 2016.
Elshehaly M, Szeto GL, Pan Z, Chen J. "ImmunoExplorer: A Web-based Multivariate Visualization System for Exploratory Analysis of Immunotherapy." 2016 International Conference on Virtual Reality and Visualization (ICVRV), Hangzhou, China, Sept 2016.

Szeto GL. “Cytokine Signatures Enable Predictive Models of Efficacy in Cancer Immunotherapy.” Gordon Conference on Immunochemistry & Immunobiology, Lucca, Italy, Jun 2016.

Kimmerling R, Szeto GL, Li J, Genshaft A, Kazer S, Borrajo J, Blainey P, Irvine DJ, Shalek A, Manalis SR. " A microfluidic platform enabling single cell RNA-seq of multigenerational lineages.” Nature Communications. 2016 Jan 6.

Arnold KB, Szeto GL, Alter G, Lauffenburger DA, Irvine DJ. “CD4+ T cell-dependent and CD4+ T cell-independent cytokine-chemokine network changes in immune responses of HIV-infected individuals. Science Signaling. 2015 Oct 20.

Szeto GL, Van Egeren D, Worku H, Sharei A, Alejandro B, Park C, Frew K, Brefo M, Mao S, Heimann M, Langer R, Jensen K, Irvine DJ. "Microfluidic squeezing for intracellular antigen loading in polyclonal B-cells as cellular vaccines." Scientific Reports. 2015 May 22.

Hanson MC, Crespo MP, Abraham W, Moynihan KD, Szeto GL, Chen SH, Melo MB, Mueller S, Irvine DJ. "Liposomal vaccines incorporating molecular adjuvants and intrastructural T-cell help promote the immunogenicity of HIV membrane-proximal external region peptides." The Journal of Clinical Investigation. 2015 May 4.

Hanson MC, Abraham W, Crespo MP, Chen SH, Liu H, Szeto GL, Kim M, Reinherz EL, Irvine DJ. "Liposomal vaccines incorporating molecular adjuvants and intrastructural T-cell help promote the immunogenicity of HIV membrane-proximal external region peptides." Vaccine. 2015 Jan 2.

Castellarnau M, Szeto GL, Love JC, Irvine DJ, Voldman J. “Stochastic Particle Barcoding for Single-Cell Tracking and Multiparametric Analysis.” Small. 2014 Sep 2.

Jones RB, O’Connor R, Mueller S, Foley M, Szeto GL, Karel D, Lichterfeld M, Kovacs C, Ostrowski MA, Trocha A, Irvine DJ, Walker BD. “Histone deacetylase inhibitors impair the elimination of HIV-infected cells by cytotoxic T-lymphocytes.” PloS Pathog. 2014 Aug 14;10(8):e1004287.

Drewes J, Szeto GL, Engle EL, Shearer GM, Zink MC, Graham DR. “Attenuation of pathogenic immune responses during acute and chronic viral infection by the tetracycline derivative minocycline.” PLoS One. 2014 Apr 14;9(4):e94375.

Liu H, Moynihan KD, Zheng Y, Szeto GL, Li AV, Huang B, Van Egeren D, Park C, Foley MH, Irvine DJ. “Structure-based programming of lymph-node targeting in molecular vaccines.” Nature. 2014 Mar 27;507(7493):519-22.

Irvine DJ, Swartz MA, Szeto GL. “Engineering synthetic vaccines using cues from natural immunity.” Nat Mater. 2013 Oct 23;12(11):978-90.

1. Name: **CLAIRE WELTY**

2. Education

Ph.D., Civil Engineering, MIT, 1989.
M.S., Environmental Engineering, The George Washington University, 1983.
B.A., Environmental Sciences, University of Virginia, 1976.

3. Academic Experience

UMBC, Professor of Environmental Engineering, 2003-present (full-time).
UMBC, Director, Center for Urban Envir. Research and Education, 2003-present (full-time).
Drexel Univ., Assoc. Director, School of Envir. Science, Eng, and Policy, 1994-2002 (full-time).
Drexel University, Associate Professor of Environmental Engineering, 1994-2003 (full-time).
Drexel University, Assistant Professor of Environmental Engineering, 1989-1994 (full-time).
MIT, Graduate Research Assistant in Civil and Envir. Eng., 1983-1988 (full-time).

4. Non-Academic Experience

US EPA, Environmental Scientist, Hazardous & Industrial Waste Div., 1976-1983 (full-time). Wrote federal regulations and support documents for control of hazardous wastes.

5. Certifications or Professional Registrations None

6. Current Membership in Professional Organizations

American Geophysical Union

7. Honors and Awards

EPA Special Service Award for developing portions of EPA's Hazardous Waste Program, 1980.
EPA Special Service Award for developing EPA Manual on Infectious Waste Mgt.,1982.
American Water Resources Association, Award for Outstanding Achievement as Conference Technical Program Chair, 2002.
Distinguished Service Award, Drexel University, for selfless dedication and service to the Environmental Program of Drexel University, 1989-2003, 2003.
Lifetime Associate of the National Research Council, National Academy of Sciences, In recognition of extraordinary service as advisor to the nation in matters of science, engineering, and health, 2008.
Director's Award, Baltimore Ecosystem Study Long-Term Ecological Research Project, 2012.

8. Service Activities

Consortium of Universities for the Advancement of Hydrologic Science, Inc. UMBC Rep (2001- present); Chair, Board of Directors, 2007; Chair, Biennial Science Meeting, 2010.
National Res. Council, Water Sci and Technol Board. Member, 2004-2007; Chair, 2007 -2010.
National Research Council, Member, Committee on the On-Site Reuse of Graywater and Stormwater: An Assessment of Risks, Costs, and Benefits, 2013 – 2015.
At-Large-Member, Chesapeake Bay Program, Scientific and Technical Advisory Committee, 2005 –2013; Review team member for Phase 6 Watershed Model, 2016.
Member, Science Advisory Board, Re-Inventing the Nation's Urban Water Infrastructure (ReNUWIt), NSF Engineering Research Center, Stanford University, 2015 – present.

Member, Steering Committee, Chesapeake Community Modeling Program, 2006 – present.
Member, Governor's Science Advisory Panel, Chesapeake and Atlantic Coastal Bay's 2010 Trust Fund, September 2008 – 2009.
Member, Board of Directors, Howard Hughes Center for AgroEcology, Wye, MD. 2011 – 2014.
Co-convenor, Special Sessions at Fall 2012, Fall 2013, and Fall 2016 AGU on urban hydrology.
Co-convenor, three special hydrogeology sessions at Fall 2015 Geological Society of America.
Member, UMBC Promotion Review Committee for CBEE Research Scientists, 2011.
Chair, UMBC Promotion Committees for Drs. Andrew Miller and Upal Ghosh, 2011-12.
Member, UMBC HPCF Governance Committee, ~2013- present.
Member, UMBC Search Committee, VP for Research, 2012-13; JCET Director, Spring 2013.
Member, Steering Committee, UMBC vision plan, 2013- 2016.
Member, UMBC Search Committee, GES Dept Chair, 2014-2015; 2015-2016.
Chair, UMBC 3rd Year Review Committee for Dr. Christopher Hennigan, 2014-15.
Chair, UMBC Promotion Committee for Mariajosé Castellanos, Fall 2015.
Member, UMBC COEIT Committee on Honors and Awards, 2015-2016.
Chair, UMBC CBEE Workload Committee, 2016-2017.

9. Publications

Barnes, M.L., C. Welty and A.J. Miller. 2015. Global topographic slope enforcement to ensure connectivity and drainage in an urban terrain. J. of Hydrologic Engineering, DOI: 10.1061/14(ASCE)HE.1943-5584.0001306
Bhaskar, A.S. and C. Welty. 2012. Water Balances Along an Urban-to-Rural Gradient of Metropolitan Baltimore, 2001–2009, Environ & Engin Geoscience, 18(1), doi:10.2113/gseegeosci.18.1.37.
Bhaskar, A.S, C. Welty, R. M. Maxwell, and A.J. Miller. 2015. Untangling the effects of urban development on subsurface storage in Baltimore. Water Resources Research, 50, doi:10.1002/2014WR016039.
Bhaskar, A.S., and C. Welty. 2015. Analysis of subsurface storage and streamflow generation in urban watersheds. Water Resources Research, 51, doi:10.1002/2014WR015607.
Bhaskar, A.S, C. Jantz, C. Welty, S. Drzyzga, and A.J. Miller. Coupling of the Water Cycle with Patterns of Urban Growth in the Baltimore Metropolitan Region, USA. J of the American Water Resources Association. Accepted 7/7/2016.
Cole, J.N., A.J. Miller, E. Stapleton, and C. Welty. In Press. Quantifying spatial patterns of channel geometry and stream incision in an urban drainage network, J. of Hydrologic Engineering. DOI:10.1061/(ASCE)HE.19435584.0001459
Cui, Z., C. Welty and R. M. Maxwell. 2014. Modeling Nitrogen Transport and Transformation in Aquifers Using a Particle-Tracking Approach. Computers and Geosciences, 70:1-14, DOI: 10.1016/j.cageo.2014.05.005.
Cui, Z., C. Welty, A.J. Gold. P. Groffman, S. Kaushal, A.J. Miller. 2016. Use of a three-dimensional reactive solute transport model for evaluation of bioreactor placement in channel restoration. J. Env Quality, 45(3), DOI: 10.2134/jeq2015.06.0330.
Seck, A., C. Welty, and R.M. Maxwell. 2015. Spin-up behavior and effects of initial conditions for an integrated hydrologic model. Water Resources Research, 51, doi:10.1002/2014WR016371.

1. Name: **PENG XU**

2. Education

Ph.D., Chemical & Biological Engineering, Rensselaer Polytechnic Institute, 2013.
M.S., Biochemical Engineering, Jiangnan University, 2006.
B.S., Biological Engineering, Jiangnan University, 2003.

3. Academic Experience

UMBC, Assistant Professor, 2016-present (full time).
MIT, Postdoctoral Fellow, 2013-2016 (full time).

4. Non-Academic Experience

None

5. Certifications or Professional Registrations

None

6. Current Membership in Professional Organizations

American Institute for Chemical Engineers
Society of Biological Engineering
International Metabolic Engineering Society

7. Honors and Awards

Chinese Government Award for Outstanding Self-financed Students Abroad, 2012
Society of Biological Engineering Travel Award – the 1st Electrofuel Conference, 2011
SUNY-Buffalo graduate student Conference Travel Award, 2010
Danisco-Genencor Scholar for Excellent Students in Biotechnology, 2008

8. Service Activities

None

9. Publications and Presentations

Xu P, Rizzoni EA, Sul SY and Stephanopoulos G. Improving metabolic pathway efficiency by statistical model based multivariate regulatory metabolic engineering. ACS Synthetic Biology, Accepted. 2016

Xu P, Qiao K, Ahn WK and Stephanopoulos G. Engineering Yarrowia lipolytica as a platform for synthesis of drop-in transportation fuels and oleochemicals. Proceedings of the National Academy of Sciences, U.S.A., 2016

Silverman, A, Qiao K, Xu P and Stephanopoulos GN. (2015) Functional overexpression and characterization of lipogenesis-related genes in the oleaginous yeast Yarrowia lipolytica. Applied Microbiology and Biotechnology. 2015, 100(8):3781-98.

Lim CG, Wong L, Bhan N, Dvora H, Xu P, Koffas M. Development of a recombinant Escherichia coli strain for overproduction of the plant pigment anthocyanin. Applied and Environmental Microbiology.2015, 81(18):6276-84. Link

Trantas EA, Koffas MA, Xu P and Ververidis F. Biotechnology of flavonoids: Metabolic engineering with commercial applications when plants produce not enough or at all. Frontiers in Plant Science, 2015, 6:7.

Bhan N, Li L, Cai C, Xu P, Linhardt R and Koffas M. Enzymatic formation of a resorcylic acid by creating a structure-guided single-point mutation in stilbene synthase. Protein Science, 2015, 24: 167-173.

Xu P, Li L, Zhang F, Stephanopoulos GN and Koffas MA. Improving fatty acids production by engineering dynamic pathway regulation and metabolic control. Proceedings of the National Academy of Sciences, U.S.A., 2014, 111(31):11299-304.

Xu P, Wang W, Li L, Bhan N, Zhang F and Koffas MA. Design and kinetic analysis of a hybrid promoter-regulator system for malonyl-CoA sensing in E. coli. ACS Chemical Biology, 2014, 9(2): 451-458.

Xu P, Gu Q; Wang W, Wong L, Bower A, Collins CH and Koffas MA. Modular optimization of multi-gene pathway for fatty acids production in E. coli. Nature Communications, 2013, 4: 1409.

Xu P, Bhan N and Koffas MA. Engineering plant metabolism into microbes: from systems biology to synthetic biology. Current Opinion in Biotechnology. 2013, 24(2): 291-299.

APPENDIX C – Equipment

Equipment available for ENCH 225:

1. Filters, decanters, stopwatches, thermometers, miscellaneous glassware and lab supplies
2. 2 mass balances
3. 6 pumps
4. Genesys 20 Thermo Spectronic Spectrophotometer
6. 7 4-cup coffee makers
7. 2 coffee grinders
8. 2 calipers
9. 7 Stirling engines
10. Terminal velocity measurement equipment (Designed by Prof. Good and built by Victor Fulda, departmental technician)
11. 7 stirrers-hotplates
12. 12 viscometers
13. 10 blenders

Equipment available for ENCH 425 and 437L

1. Hampden Model H-6857 Water Flow Heat Transfer Demonstrator
2. Sartorious Biostat Aplus Fermentor *
3. Fixed and Fluidized Bed Apparatus. Updated to digital manometer in 2006.
4. Custom built recirculating water bath for experiments of unsteady-state heat conduction in Plexiglas and stainless steel cylinders.
5. Agilent 8453 UV-Vis Spectrometer. Peristaltic pump, flow cell, stirred temperature-controlled flask for carrying out kinetics experiments*.
6. Labjack U6 Analog to Digital Conversion Boards for data acquisition (3 boards are available).
7. Custom built apparatus for measuring tank efflux for various drainage tube diameters and lengths.
8. Custom built apparatus for measuring the pressure drop of water pumped through copper and galvanized steel piping*.
9. Apparatus for measuring the pressure drop of water pumped through various valves, fittings and pipe diameters.
10. Custom built columns for measuring humidification of air and absorption/stripping processes.
11. Various basic chemicals and equipment, including water and air pumps, stir/hot plates, stop-watches, tubing (copper and plastic), flowmeters, manometers, balances, pH meter, mixers
12. Mini-refrigerator*
13. Champion F-33D centrifuge*
14. Reichert light microscope
15. General use computers

Equipment available for ENCH 485L

1. Eppendorf Pipetters *
2. pH Meter
3. Stirrer-Hotplates*
4. Analytical Lab Balance*
5. DNA Classroom Electrophoresis Setup*
6. ELISA Protein Assay Supplies*
7. Diafiltration Supplies and Reagents*
8. Pharmacia Biotech GradiFrac Chromatography System and Supplies
9. SDS-Page Experiment Supplies*
10. Sartorious Biostat Aplus Fermentor*
11. Labconco Laminar Flow Hood*
12. Fluorometrix pH & DO sensors*
13. Sartorius BS-1 Incubator-Shaker*
14. Agilent 8453 UV-Vis Spectrometer*
15. Varian Cary Eclipse Fluorescence Spectrophotometer*
16. Amersham Biosciences Aktaprime Plus FPLC (Fast Protein Liquid Chromatography)
17. Salvage of Waters HPLC Pump/UV Detector
18. Plate reader (BioTec)*
19. General use computers
20. Tensile Testing system (MTS system)
21. Microscope with camera for viewing slides and cell cultures in brightfield and phase (Amscope)

*Item was purchased in 2007 or later

APPENDIX D – Institutional Summary

1. **The Institution**

   a. University of Maryland, Baltimore County
      1000 Hilltop Circle
      Baltimore, Maryland 21250

   b. Dr. Freeman A. Hrabowski, III, President

   c. Dr. Mark Marten, Professor and Chair
      Chemical, Biochemical and Environmental Engineering Department

   d. Name of Organizations by which the Institution is now accredited, and the dates of initial and most recent accreditation evaluation.

Accrediting Organization	Program Name	Initial Evaluation	Most Recent Evaluation
Middle States Commission on Higher Education 3624 Market Street Philadelphia PA 19104 210-662-5606	UMBC	1976	2016 (next: 2021)
ABET, Inc. 111 Market Pl., Suite 1050 Baltimore MD 21202 410-347-7700	Chemical Engineering	1987	2011 (next: 2017)
	Computer Engineering	1999	2011 (next: 2017)
	Computer Science	1999	2011 (next: 2017)
	Mechanical Engineering	1987	2011 (next: 2017)
National Council for Accreditation of Teacher Education 2010 Massachusetts Ave NW, Suite 500 Washington DC 20036 202-466-7496 Maryland State Department of Education 200 West Baltimore Street Baltimore MD 21201 410-767-0600	Early Childhood Education Elementary Education English Secondary Foreign Language Science Social Studies Teaching English to Speakers of Other Languages	1999	2011 (next: 2018)

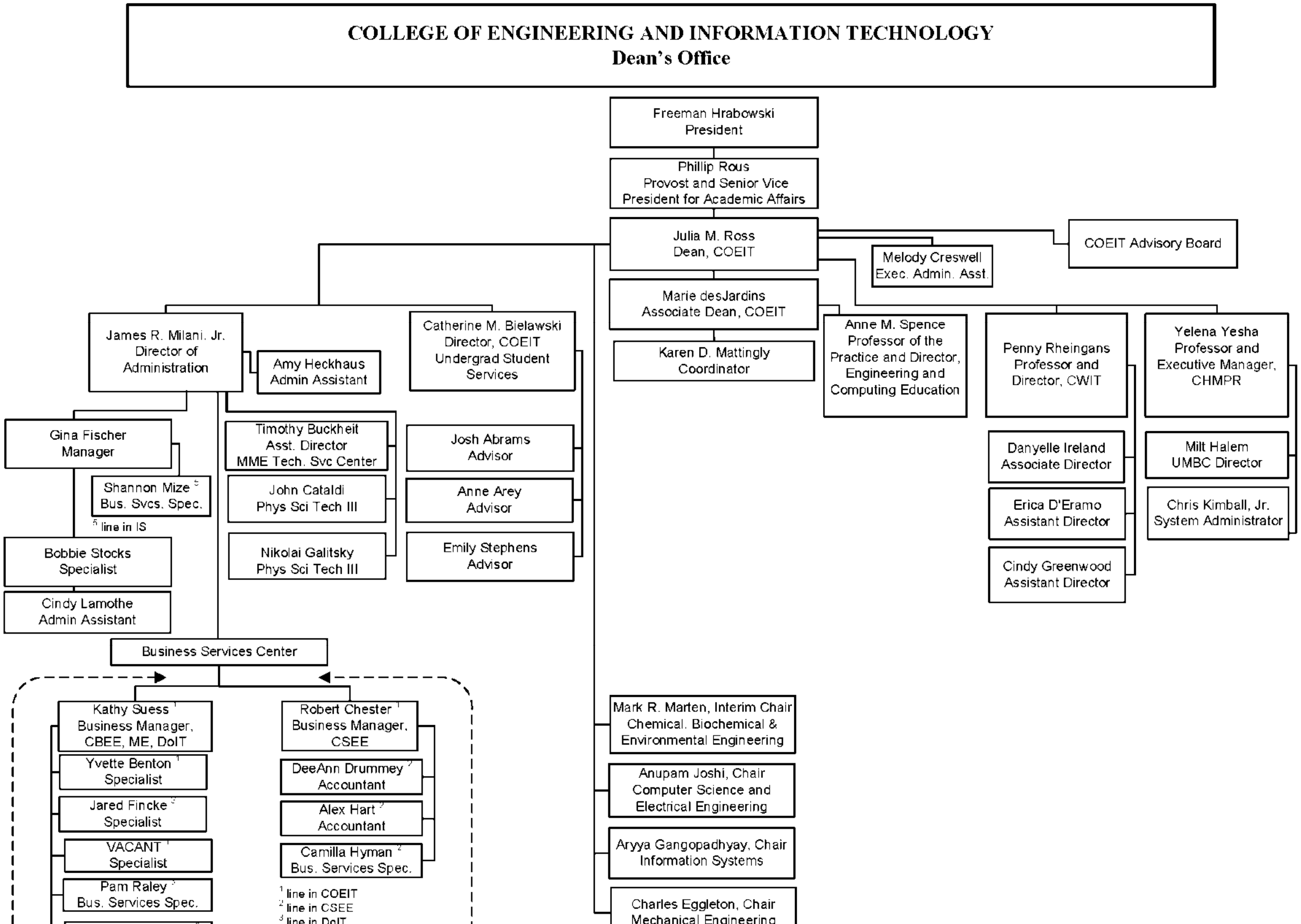
2. Type of Control

Established as part of the University Systems of Maryland (USM) in 1966, the University of Maryland, Baltimore County (UMBC) is a public, state-supported, co-educational institution. The University System of Maryland comprises 12 institutions, two regional higher education centers, and a system office. USM provides access to excellent higher education opportunities, performs groundbreaking research, offers vital services to communities and individuals, and fuels economic and workforce development. As a public system of higher education, USM advances the State of Maryland and benefits all of society. A President governs each of the twelve campuses autonomously. A Chancellor is the chief executive officer of the USM. A Board of Regents oversees the System. For budgetary and other fiscal matters, UMBC falls under the purview of the Governor of the State of Maryland, The Maryland Higher Education Commission (MHEC), and the Maryland State Legislature. The Carnegie Foundation ranks UMBC in the category of Research Universities with high research activity.

3. Educational Unit

The Program is located in the Department of Chemical, Biochemical and Environmental Engineering in the College of Engineering and Information Technology. The Chair of the Department reports to the Dean of the College (Dr. Julia M. Ross, Dean of Engineering and Information Technology). The Dean reports directly to the Provost (Dr. Philip Rous, Provost and Senior Vice President for Academic Affairs). The Provost reports to the President of the University (Dr. Freeman A. Hrabowski, III, President).

College of Engineering and Information Technology Organizational Chart



Created: August 2008
Updated: September 2016

4. Academic Support Units

Biological Sciences

Department Chair

Philip Farabaugh, Ph.D.
Professor, Biological Sciences
Phone: 410-455-3018
E-mail: farabaug@umbc.edu

Chemistry and Biochemistry

Department Chair

Zeev Rosenzweig, Ph.D.
Professor, Chemistry and Biochemistry
Phone: 410-455-2521
E-mail: zrosenzw@umbc.edu

English

Department Chair

Orianne Smith, Ph.D.
Associate Professor, English
Affiliate Associate Professor, Gender and Women's Studies
Phone: 410-455-2138
E-mail: osmith@umbc.edu

Mathematics and Statistics

Department Chair

Rouben Rostamian, Ph.D.
Professor, Mathematics and Statistics
Phone: 410-455-2458
E-mail: rostamian@umbc.edu

Physics

Department Chair

Dr. L. Michael Hayden
Professor, Physics
Phone: 410-455-3199
E-mail: hayden@umbc.edu

5. Non-Academic Support Units

Albin O. Kuhn Library and Gallery

Director

Patrick Dawson
Phone: 410-455-2356

E-mail: pdawson@umbc.edu

Career Center
Director
Christine Routzahn
Phone: 410-455-3671
E-mail: routzahn@umbc.edu

Center for Women in Technology
Director
Penny Rheingans, Ph.D.
Professor, Computer Science and Electrical Engineering
Phone: 410-455-3554
E-mail: rheingan@umbc.edu

COEIT Computer Facilities
Computer System Manager
Geoff Weiss
Computer Science and Electrical Engineering
Phone: 410-455-3959
E-mail: gweiss@cs.umbc.edu

COEIT Undergraduate Student Services
Director
Catherine Bielawski
Phone: 410-455-1641
E-mail: bielawsk@umbc.edu

Division of Information Technology
Vice President of Information Technology and CIO
Jack Suess
Phone: 410-455-2582
E-mail: jack@umbc.edu

Learning Resources Center
Director
Cassie Bichy
Phone: 410-455-2447
E-mail: bichy@umbc.edu

The Shriver Center
Director
Michele K. Wolff
Phone: 410-455-2493
E-mail: wolff@umbc.edu

6. Credit Unit

One semester credit hour represents one class hour or three laboratory hours per week. The academic year consists of two 14.5-week semesters (exclusive of finals), two 6-week summer sessions, one 8-week summer session, and one 4-week winter session. Students are required to attend a minimum of one 50-minute class period per week for each unit of academic credit during the regular semester. Some classes may require more than the minimum requirement.

7. Tables

Please see Tables D-1 and D-2 on the following pages.

Table D-1. Enrollment and Degree Data*

Chemical Engineering (B.S., M.S. and Ph.D.)

			Enrollment year					Total	Total	Enrollment			Total	Total	Degrees Conferred (AY)[2]		
Year	Fall	FT/ PT	1st	2nd	3rd	4th	Unclas	UG	UG (FT+ PT)	MS	PhD	Grad Non-Degree	Grad[1]	Grad	BS[4]	MS	PhD
Current	2016[3]	FT	34	62	66	126	0	288	326	3	17	0	20	23	53	8	1
		PT	1	2	11	24	0	38		3	0	0	3				
1	2015[3]	FT	66	66	86	125	0	343	369	6	14	0	20	27	44	2	4
		PT	0	0	10	16	0	26		7	0	0	7				
2	2014	FT	52	79	97	91	0	319	357	2	15	0	17	22	28	4	3
		PT	1	6	9	22	0	38		4	1	0	5				
3	2013	FT	55	70	59	74	0	258	281	5	23	0	28	28	33	11	1
		PT	0	1	5	17	0	23		0	0	0	0				
4	2012	FT	62	47	62	85	0	256	278	6	22	0	28	31	37	10	2
		PT	2	1	6	13	0	22		3	0	0	3				
5	2011	FT	31	50	48	78	0	207	227	12	19	0	31	37	32	6	4
		PT	0	3	5	12	0	20		4	2	0	6				
6	2010	FT	40	48	49	71	0	208	225	10	24	0	34	37	24	5	1
		PT	1	0	6	10	0	17		1	2	0	3				

* Enrollment Data as of 10th day enrollments, Fall semesters. FY degrees include August, December and May graduates. For example, AY2010 degrees were awarded in August 2009, December 2009 and May 2010.

Source: UMBC Office of Institutional Research and Decision Support (IRADS) : "Undergraduate & Graduate Headcount Enrollment by Plan (exclude LOA)" and "COEIT Degrees Awarded"

[1]Total Grad counts do not include nondegree seeking enrollments
[2]Total Degrees Conferred (AY) includes Bachelors and second Bachelors
[3]Includes Pre-ENCH, which are students in their first year who have declared their desire to major in Chemical Engineering
[4]The BS degrees total reported here differs slightly from the total in Table C-1 in the Background Section due to differences in the database query methods used.

Table D-2. Personnel

Chemical Engineering

Fall 2016

	HEAD COUNT		FTE[2]
	FT	PT	
Faculty (tenure-track)	12	0	12
Other Faculty (excluding student Assistants)	3	0	3
Postdocs	4	1	4.33
Nonfaculty Researchers	7	1	7.33
Student Research Assistants	27	0	27
Fellows	0	0	0
Student Teaching Assistants	6	0	6
Technicians/Specialists [1]	2	0	2
Office/Clerical Employees [1]	2	0	2

[1] As reported in Department of Chemical, Biochemical & Environmental Engineering, not necessarily within the Chemical Engineering program solely.

[2] FTE calculated at a rate of 1 per unit for FT personnel and 0.33 per unit for PT personnel.

Signature Attesting to Compliance

By signing below, I attest to the following:

That the Chemical Engineering Program has conducted an honest assessment of compliance and has provided a complete and accurate disclosure of timely information regarding compliance with ABET's *Criteria for Accrediting Engineering Programs* to include the General Criteria and any applicable Program Criteria, and the ABET *Accreditation Policy and Procedure Manual.*

______**Julia M. Ross** ________________
Dean's Name (As indicated on the RFE)

Julia M. Ross ____________________ 6/28/17 ____________

Signature