AY23-1 Chemical Engineering Course and Program Brief

LTC Matthew Armstrong
LTC Sam Cowart
Dr. Simuck Yuk
MAJ Caspar Yi
MAJ Patrick Bowers
Dr. Enoch Nagelli
Dr. Andy Biaglow
MAJ Jeff Chin
LTC John Belanger
CPT(P) Galen Mandes

05 April 2022

Agenda

- Course Briefings
  - -CH365
  - -CH485
  - -CH363
  - -CH350
  - -CH459
- Summer training for CH459 Transition
- Signature Writing Event (SWE) in CH459
- Bioengineering: Curriculum Committee Memos for CH300 and CH350
  - For cadets to sign up for courses AY24 and beyond: memos
  - CH350 Update going into AY23
- ABET and Advisory Board Update (07APR22)
  - Dinner, Hotel, and Schedule
- Majors Update from Class of 2025
- Recruiting/Mentorship plan for inbound faculty

CH365: Chemical Engineering Thermodynamics

Course Director: Dr. Biaglow

Course Supervisor: Dr. Nagelli

Credit Hours: 3.0 (BS=0, ET=3.0, MA=0)
Prerequisites: CH363, CH364, MA366, MC312
Co-requisite: None
Lessons: 40 @ 55 min
Special Requirements: None

This course covers the body of thermodynamic knowledge necessary for understanding modern chemical process simulation. Students learn the theory behind the thermodynamic methods used in the software. The course includes calculus- and numerical-based thermodynamics approaches for determining the properties of substances, solutions, and multiphase mixtures. Topics include equations of state, pure component properties, transport properties, properties of mixtures, fugacity, excess properties, activity coefficients, and phase equilibria. The problems in the course emphasize engineering applications. Topics covered in class are related to real systems through the use of chemical process simulators.

Topics – by Chapter

Chemical Engineering Thermodynamics, Smith, van Ness, Abbott, and Swihart, 9th Edition (2021)

- Introduction (Ch. 1)
- First Law (Ch. 2)
- Equations of State (Ch. 3)
- Heat (Ch. 4)
- Entropy and Second Law (Ch. 5)
- Fluid Properties (Ch. 6)
- Equilibrium (Ch. 10)
- Solution Thermodynamics (Ch. 11)

Course Assessment – Items from Section III

Sustain:

Writing project - resume exercise involved intense use of instructor time but positive changes were observed; many teachable moments

Capstone project – calculation of properties and comparison with CAD

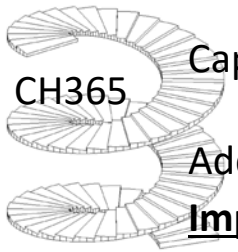
Addition of writing to capstone

Improve:

More emphasis on Ch 11, specifically excess properties

More practice on calculating fugacity and activity.

Use of writing rubric to assess capstone.



Assessment – Graded Events

1 *Term End Exam @ 500 pts:	500	22.42%
1 *Capstone Design Project @ 300 pts	300	13.45%
3 *Capstone IPRs @ 30 pts each:	90	4.04%
3 *WPRs @ 200 pts each:	600	26.91%
64 *Problems @ 10 pts each:	640	28.70%
1 *Writing Assignment @ 100 pts:	100	4.48%
Total:	2230	100.00%
*Individual Points :	2230	100%

CH485: Heat and Mass Transfer

Course Director: LTC Sam Cowart

Course Supervisor: Dr. Biaglow

Credit Hours: 3.5 (BS=0, ET=3.5, MA=0)
Prerequisites: MA364 and MC312
Co-requisite: None
Lessons: 30 @ 75 min, 7 @ 120 min
Special Requirements: None

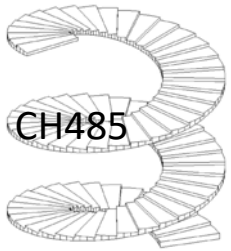
This course includes the study of the mechanisms of energy and mass transport, with special emphasis on applications in engineering systems. Coverage includes Fourier's Law of Heat Conduction, and Fick's Law of Diffusion, the development of shell energy and species balances, and the use of these equations to solve for temperature and concentration profiles in chemical engineering systems. An important emphasis in the course is the use of transport equations to understand species diffusion, convection, and chemical reaction in equipment design.

Topics

Mass and Heat Transfer, T.W. Fraser Russell, A.S. Robinson, and N.J. Wagner, Cambridge University Press, Copyright 2008

- Introduction (1 Lesson)
- Macroscopic mass, energy, and species balances
  - Chemical reactors (2 lessons)
  - Heat exchangers (4 lessons)
  - Mass contactors (2 lessons)
- Microscopic mass, energy, and species balances
  - Conduction and diffusion (9 lessons)
  - Convective heat and mass transfer (7 lessons)
  - Transport Analogies (4 lessons)

Course Assessment – Items from Section III



Sustain:

Problem solving days prior to WPR/ICPS

Lesson structure & content*

Improve:

- Continue to revise problem sets – Too much reliance on old solutions.
- *Incorporate radiation heat transfer material (external source).
- Update Lab 6 – Arnold Cell
  - Hands-on in the ChemE Lab, with conditions allowing experimental data to be taken in ~30 minutes.
  - Eliminates reliance on pre-recorded video of acetone diffusion.

Assessment – Graded Events

8 *Problem Sets @ 50 pts each:	400	18%
2 *In-Class Prob. Sets @ 100 pts each:	200	9%
3 *WPRs @ 200 pts each:	600	27%
1 *Writing Assignment @ 200 pts:	225	10%
7 Labs @ 40 pts each:	280	13%
1 *Term End Exam @ 500 pts:	500	23%
Total:	2205	
*Individual Points :	1925	87%

CH363: Separations Processes

Course Director: Dr. Enoch Nagelli

Course Supervisor: Dr. Biaglow

Credit Hours: 3.5 (BS=0, ET=3.5, MA=0)
Prerequisites: CH362
Co-requisite: None
Lessons: 30 @ 75 min, 7 @ 120 min
Special Requirements: None

This course covers methods for the physical separation of chemicals. Topics include dew point and bubble point calculations, adiabatic flash, distillation, chromatography, liquid-liquid and gas-liquid absorption/stripping. Students are taught the significance of staging of unit operations. Heavy emphasis is placed on theory of operations, numerical methods of solution, and simulation.

Topics – by Chapter

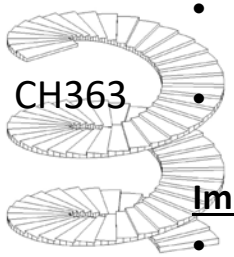
Separation Process Principles, 4th Ed., by J.D. Seader, E.J. Henley and D.K. Roper

- Introduction to Separations/DOF Analysis (Ch. 1)
- Vapor-liquid, gas-liquid, solid-liquid, flash(Ch. 4)
- Cascading configurations (Ch. 5)
- Designing trayed towers and packed columns (Ch. 6)
- Optimizing towers and columns (Ch. 7)
- Liquid-liquid extraction (Ch. 8)
- Multi-component distillation (Ch. 9)
- Capstone Project

Course Assessment – Items from Section III

Sustain:

- Technical Writing: Written Research Paper
- Capstone project – Ties all key concepts together. Assesses communication outcome.
- ChemCAD use in concert with theory/ every day CHEMCAD



Improve:

- Need extra distillation lesson in block 3; topic needs more treatment and fits better in block 3
- Improve cadets reliance on the text as a resource
- **More** instructor problems for HW/ less book problems

Assessment – Graded Events

8 Problem Sets @ 40 pts each:	320	13.3%	
4 *In-Class Prob. Sets @ 75 pts each:		300	12.5%
3 *WPRs @ 200 pts each:		600	25.0%
1 *Research Paper @ 100 pts:	100	4.2%	
7 *Labs @ 40 pts each:		280	11.6%
1 *Term End Exam @ 500 pts:	500	20.8%	
1 *Capstone		300	12.5%
Total:		2400	
*Individual Points :		1820	75.8%

CH350: Introduction to Bioengineering

Course Director: Dr. Simuck Yuk

Course Supervisor: COL Burpo

Credit Hours: 3.0 (BS=0, ET=3.0, MA=0)
Prerequisites:
Co-requisite: None
Lessons: 30 @ 75 min
Special Requirements: None

The purpose of this course is to provide the introductory knowledge for understanding the biotechnology/bioprocessing engineering. Topic includes enzyme kinetics, molecular biology, cell growth, bioreactors, and bioprocesses. The bioprocess control and its application to different biological systems are covered in the classroom instruction. An important emphasis is made on the use of kinetics and process controls on the biological systems for engineering application.

Topics – by Chapter

Bioprocess Engineering Basic Concepts, 3rd Ed., by Michael L. Shulter, Fikret Kargi, Matthew DeLisa, Prentice Hall.

Quantitative Fundamentals of Molecular and Cellular Bioengineering, by K. Dane Wittrup, Brice Tidor, Benjamin J. Hackel, and Casim A. Sarkar, The MIT Press.

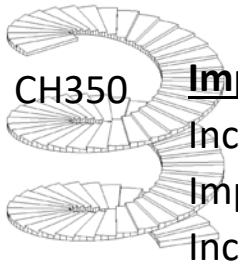
- Introduction
- Enzyme Kinetics
- Central Dogma to Molecular Biology
- Cell Growth
- Bioreactor Selection
- Bioprocess Consideration

Course Assessment – Items from Section III

Sustain:

Continue to use of DeLisa (3rd Ed.)

Continue to introduce problem demos



Improve:

Increase number of in-class problem demos.

Improve problem sets and WRPs.

Increase number of coding-related problems.

Assessment – Graded Events

1 *Capstone Presentation	100	9%
1 *Capstone Paper	200	18%
2 *WPRs	400	36%
5 Problem Sets(50pts/ea.)	250	23%
1 *Discussion	150	14%
Total:	1100	100.00%

CH459: Chemical Engineering Lab

Course Director: LTC Belanger

Course Supervisor: LTC Cowart/Dr. Nagelli

Credit Hours: 3.5 (BS=0, ET=3.5, MA=0)
Prerequisites: CH362/CH363/CH364
Co-requisite: None
Lessons: 40 @ 120 min, 7 @ 120 min
Special Requirements: None

This course provides laboratory experience in selected chemical engineering unit operations, such as gas absorption, evaporation, distillation, liquid-liquid extraction, cooling tower, heat exchanger, and chemical reactors. Process control and process safety are emphasized in laboratory and classroom instruction. Written and oral reports required.

1. Unit Operations of Chemical Engineering, 7th Edition, by Warren L. McCabe, Julian C. Smith and Peter Harriott; McGraw-Hill, 2005.

2. Plant Design and Economics for Chemical Engineers 5th ed., Peters, Max S. and Klaus D. Timmerhause, McGraw-Hill, New York 2003, ISBN-10: 0071240446

1. Batch and CSTR — EC: Short Ht Exchgnr
2. Cooling Tower
3. Hydrogen Fuel Cell
4. Single/Double Effect Evaporator
5. Distillation
6. Carbon Dioxide Absorber

Course Assessment – Items from Section III

Sustain:

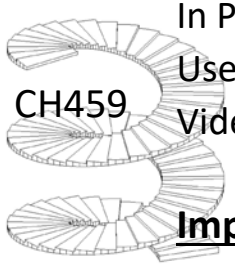
Technical Writing: Written Lab Reports/ Posters/ Executive Sum.

SACHE Modules

In Progress Reviews (IPRs)

Use of CHEMCAD to model all lab data

Videos of each experiment for cadets to develop procedure



Improve:

Cadet peer evaluations at assigned role during lab rotation; make sure cadets assess the cadets performance at role

More practice with setting up flow charts by hand and labeling streams with process variables with units

Assessment – Graded Events

6 Lab HWs@ 20 pts each	120*	4.1%
6 Lab Exec. Sum/ Poster/ Report	600	20.5%
6 IPRs @25 pts ea	150	5.1%
6 Lab Execution (aka. lab rubric)	450	15.4%
2 *WPRs @ 550 pts each:	1100*	37.7%
1 *Term End Exam @ 500 pts:	500*	17.1%
Total:	2920	
*Individual Points :	1720	58.9%

FDW for CH459: Summer Training

- FDW Mentors: Dr. Enoch Nagelli (CH459) and LTC Sam Cowart (CH101 and CH459)
- FDW Mentee: LTC Belanger
- Summer of 2022: **27JUN-01JULY (CH101) and 01JULY-29JULY (CH459)**
  - LTC Belanger to attend beginning portion of CH101 FDW
  - Schedule daily will include experiments and calculations overview/discussion
- Round Robin 1 and 2 Experiments, Procedure and Execution
- Process controls analysis, P&ID, mass & energy balance calculations, and other key calculations
- Process simulation modeling via ChemCAD

SWE in CH459: EXSUM

- EXSUM (Individual submission) with established Rubric for Assessment in Course
    - Heat Exchanger Lab

- Cadet teams assigned a lab hour to conduct experiment and collect data
    - Pre-safety startup review and procedure
    - Laplace block controls analysis
    - P&ID
    - Calculations and ChemCAD process simulation model
    - Error Analysis

- ChemE Faculty as Mentors for each cadet in course
    - Scheduled IPRs

Bioengineering

- Curriculum Committee Memos for CH300 and CH350
  - Allows class of 2024 and 2025 to enroll into courses once approved
  - Future offerings in Redbook

  - Memorandum for permanently placing CH300 and CH350 in the Redbook was written and program review complete. Currently, pending approval from COL Burpo and COL James.

CH350 Update

- DeLisa's textbook generally gives a good overview of how major engineering concepts (mostly from chemical engineering) can be modified and readjusted for various biological systems.
  1) Some key concepts introduced in the book can better be understood for cadets who have taken CH363 and CH364.
  2) Units introduced in the book are sometimes misleading.

- The introduction of additional coding-related problems during the class can enhance cadet's understanding on the quantitative analysis of biological pathways and system designs.

ABET Advisory Board (07-08APR22)

- In-person meeting with the Teams option for those who cannot travel
- Combination of representatives from our constituencies:
  - Industry
  - Academia
  - Army
- Review data; take survey; interact with Chemical Engineering Cows and Firsties
- Give curriculum advice
- Inform program decisions
- Helps write the program educational objectives and mission statement (these are ABET requirements)

Advisory Board

No	Name	Title	School - Company	Email	Attending ?	In-persion or remote?
1	Lucy Hair	EleCent Team Leader	LLNL (Lawrence Livermore National Laboratory)	hair1@llnl.gov	Yes	In-Person
2	COL (Ret) Paul Dietrich	Chemical Officer	Chemical Officer/Industry	paul@the-dietrichs.com	Yes	In-Person
3	Kisondra Tanev	Vice President	Bank of America	kisondra@gmail.com	Yes	In-Person
4	Donald Glaser	President	Simulation Solutions	dglaser@simulation-solutions.com	Yes	In-Person
5	Matt Garvey	Engineer	Simulation Solutions	mgarvey@simulation-solutions.com	Yes	In-Person
6	Matthew Liberatore	Professor	University of Toledo	matthew.liberatore@Utoledo.edu	Yes	In-Person
7	COL Aaron Hill	Academy Professor	USMA; CME	aaron.hill@westpoint.edu	Yes	In-Person
8	Kevin Shipe	Automation Engineer	NALCO Champion	kevin.a.shipe@gmail.com	Yes	Remote
9	Patrick Underhill	Professor	RPI	underhill@rpi.edu	Yes	Remote
10	Gautham Krishnamoorthy	Professor	UND	gautham.krishnamoorthy@und.com	Yes	Remote
11	Kelly Schutz	Assistant Professor	Lehigh University	kes513@lehigh.edu	Yes	Remote
	Lynn Walker	Professor	Carnegie Mellon University	lwalker@anderw.cmu.edu		
	Greg Ritch	COL(RET)/ Engineering Officer	MIL/Industry	garitch@cvzoom.net		
	Mike Deforest	Industry, Chem E (Old Grad '07)	SMK Packaging	mike@smkpackaging.com		

Proposed Agenda for Advisory Board Meeting

Date	Time	Event	Location	OIC	Task
7APR	NLT1700	Pick up 15 PAX van	Motorpool	MAJ Yi/ MAJ Chin	
	1530	Dr. Matthew Liberatore Chem E. Seminar (abstract to follow)	BH465 (Chair-side)	CPT(P) Bowers/ CPT(P) Mandes	
	1830 - UTC	Dinner	Bear Mountin Inn Fort Montgomery, NY	LTC Armstrong	make reservation
8APR	0730	Pick up	Holiday Inn Express 1106 Route 9W Fort Montgomery, NY (845) 446 - 4277	MAJ Chin	Drive van
	0745 - 0800	Arrival and lite breakfast	Bartlett Hall 465 (table side)	LTC Armstrong Dr. Nagelli	Breakfast
	0800 - 0830	Session1: Introductory remarks and ABET orientation	BH465	COL Burpo LTC Armstrong	
	0830 - 0920	Session2: Program Assessment Student Outcomes Assessment Discussion of Program Objectives	BH465		
	0920 - 0935	Board Surveys	BH465	LTC Armstrong	Survey Parts 1 & 2
	0935 - 0950	Session3: CH367 Update	BH465 (table side)	COL James	
	1000 - 1050	Career Panel (Cows)	BH465 (chair side)	LTC Armstrong	
	1050 - 1115	Cadet Discussions (Fisties and Cows)	BH465 (chair side)		
	1130 - 1300	Lunch/Firstie Mock Interview Round Robin	BH465	Dr. Nagelli	
	1300 - 1330	Board backbrief on cadet interactions	BH465	LTC Armstrong	
				Dr. Nagelli	
	1340 - 1430	Session 4: Future Challenges	BH465	LTC Armstrong	
	1430 - 1455	Admin and Unit Ops Lab Tour	SBBH	Dr. Nagelli	
	1500 - 1600	Wrap up	BH465		

Majors Update Class of 2025

- Currently 36 cadets declared ChemE
  - 2 sections of major ChemE course
  - CH459 - 3 sections a possibility similar to AY20

Recruiting Plan for Faculty in ChemE

- Communication and outreach by current ChemE faculty
  - Research that leverages the department's current research threads for execution when inbound
  - Thesis committee members (non-voting) for senior faculty (Dr. Biaglow, LTC Cowart, Dr. Yuk, and Dr. Nagelli)
  - Collaboration between faculty researchers and PI at respective universities

	Future Faculty Member	ACS Start	USMA Arrival	School	Cost Category	Research Focus
	**LTC John Belanger** (Sponsor LTC Cowart)	AUG 2019	JUN 2022	Stanford	High	Complex Materials
	**CPT Sam Lowell** (Sponsor MAJ Bowers)	N/A	JUN 2022	NPS	N/A	NPS Thesis: Reduction Expansion Synthesis for Magnetic Alloy Powders
	**CPT Louis Tobergte** (Sponsor CPT(P) Mandes)	AUG 2022	JUN 2023	Carnegie Mellon	High	Thesis completed at Leeds: Water
	**CPT Liz Golonski** (Sponsor MAJ Bowers)	AUG 2022	JUN 2024	Colorado School of Mines	Low	Catalytic membrane reactors
	**CPT Nijel Rogers** (Sponsor CPT(P) Mandes)	AUG 2022	JUN 2024	Princeton University	High	Soft matter
	**CPT Christopher Stewart** (Sponsor CPT Lowell)	AUG 2023	JUN 2025	TBD	TBD	TBD

LTC John Belanger

- Sponsored by LTC Cowart
- CH459 mentor is Dr. Nagelli
- Programmed for CH459, and CH400 (eventually)
- AIChE OIC?
- Will conduct CH459 FDW Summer 2022
- Currently researching complex material/ tree sap/ kino/ rheology

CPT Sam Lowell

- Sponsored by MAJ Bowers
  - Sub: Dr. Yuk and CPT(P) Mandes
- Completed M.S. degree directly after USMA graduation at NPS (MechE)

Questions

Backup Slides

AY22		AY23		AY24	
AY22-1 (Fall)	AY22-2 (Spring)	AY23-1 (Fall)	AY23-2 (Spring)	AY24-1 (Fall)	AY24-2 (Spring)
CH363 (Armstrong)	CH362 (Cowart)	CH363 (Nagelli)	CH362 (Cowart)	CH363 (Nagelli)	CH362 (Cowart)
CH459 (Nagelli)	CH364 (Yuk)	CH459 (Belanger)	CH364 (Yuk)	CH459 (Belanger)	CH364 (Yuk)
CH485 (Cowart)	CH402 (Biaglow)	CH485 (Cowart)	CH402 (Biaglow)	CH485 (Cowart)	CH402 (Biaglow)
CH365 (Biaglow)	CH400 (Nagelli)	CH365 (Biaglow)	CH400 (Nagelli)	CH365 (Biaglow)	CH400 (Nagelli)
CH350 (Yuk)	CH367 (James)	CH350 (Yuk)	CH367 (James)	CH350 (Yuk)	CH367 (James)
	CH300 (Burpo)		CH300 (Burpo)		CH300 (Burpo)
	CH450 (Burpo)		CH450 (Burpo)		CH450 (Burpo)
Yi (2x GC sections)	Mandes (2x GC sections)	Mandes (GC)	Mandes (GC)	Mandes (GC)	Mandes (GC)
Bowers (GC 3x sections)	Bowers (GC 3x sections)	Yi (GC)	Belanger (GC)	Bowers (GC)	Bowers (GC)
Mandes (GC 3x sections)	Yi (2x GC sections)	Chin (GC+S1)	Chin (GC+S1)	Lowell (GC)	Lowell (GC)
Chin (2x sections+S1)	Chin (2x sections+S1)	Bowers (GC)	Bowers (GC)		Belanger (GC)
		Lowell(GC)	Yi (2x GC sections)		
			Lowell(GC)		

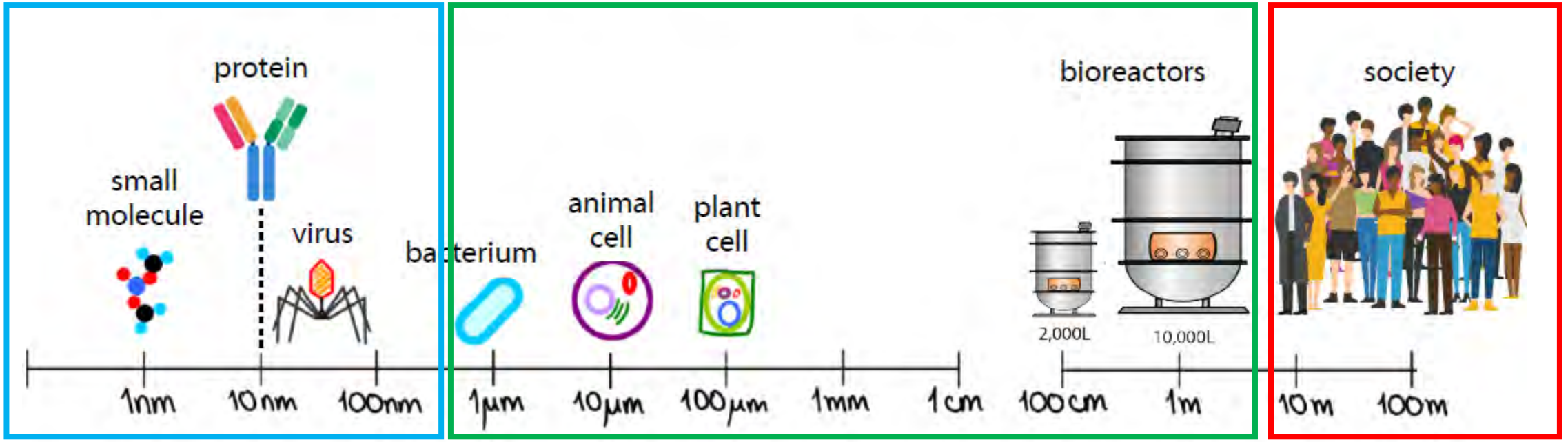
AY25		AY26		AY27	
AY25-1 (Fall)	AY25-2 (Spring)	AY25-1 (Fall)	AY25-2 (Spring)	AY25-1 (Fall)	AY25-2 (Spring)
CH363 (Nagelli)	CH362 (Cowart)	CH363 (Nagelli)	CH362 (Cowart)	CH363 (Nagelli)	CH362 (Cowart)
CH459 (Belanger)	CH364 (Yuk)	CH459 (Belanger?)	CH364 (Yuk)	CH459 (Belanger?)	CH364 (Yuk)
CH485 (Cowart)	CH402 (Biaglow)	CH485 (Cowart)	CH402 (Biaglow)	CH485 (Cowart)	CH402 (Biaglow)
CH365 (Biaglow)	CH400 (Belanger)	CH365 (Biaglow)	CH400 (Nagelli)	CH365 (Biaglow)	CH400 (Nagelli)
CH350 (Yuk)	CH367 (James)	CH350 (Yuk)	CH367 (James)	CH350 (Yuk)	CH367 (James)
	CH300 (Burpo)		CH300 (Burpo)		CH300 (Burpo)
	CH450 (Burpo)		CH450 (Burpo)		CH300 (Burpo)
Rogers (GC)	Rogers (GC)	Rogers (GC)	Rogers (GC)	Rogers (GC)	Rogers (GC)
Lowell(GC)	Lowell(GC)	Golonski(GC)	Golonski(GC)	Golonski(GC)	Golonski(GC)
Golonski(GC)	Golonski(GC)				

Bioengineering

- Curriculum Memoranda completed and approved by Curriculum Committee for CH300 & CH350
- Bioengineering track
- 3-course engineering sequence
- Bioengineering minor (2-3 years)
- Bioengineering major (5 – 15+ years); ABET accredited ~2030

CH350 Course Layout

Molecular – Cellular – Bioreactor/Purification Systems – Societal



Block 1 - Biomolecular Considerations 12 lectures (plus 1 WPR)
LSN 1-13

Block 2 - Cellular Considerations 8 lectures (plus 1 WPR)
LSN 14 - 22

Block 3 - Downstream Considerations 6 lectures (Plus 2 lessons of Group Presentations)
LSN 23-30

CH350 Detailed Overview

CH350 - Bioprocess Engineering (AY 22-1)

2-Days during X2-hr (XXXX-XXXX) in BH331 Text: Bioprocess Engineering: Basic Concepts, 3rd Ed., Shuler, Kargi & DeLisa

Day	2-Day	LSN	Subject	Reading	Instructor	Event	Points
			Block I: Biomolecular Considerations				
Th	21-Jan	1	Introduction to Bioprocess Engineering	Ch 1 (Schuler et al)	Dr. Yuk		
M	25-Jan	2	Introduction to Cells and Biomolecules Part 1	Ch 2.1 (Schuler et al)	Dr. Yuk		
Th	28-Jan	3	Introduction to Cells and Biomolecules Part 2	Ch 2.2-2.3 (Schuler et al)	Dr. Yuk	Problem Set 1 Due	50/50
M	1-Feb	4	Enzyme kinetics and immobilized enzyme systems Part 1	Ch 3.1-3.2.3.1 (Schuler et al)	Dr. Yuk		
F	5-Feb	5	Enzyme kinetics and immobilized enzyme systems Part 2	Ch 3.2.3.2- 3.2.6 (Schuler et al) Skim: MIT Press Chap 3.3	Dr. Yuk	Discussion Grade 1	30/80
Tu	9-Feb	6	Enzyme kinetics and immobilized enzyme systems Part 3	Ch 3.3 (Schuler et al)	Dr. Yuk		
Th	11-Feb	7	Non-covalent binding interactions; Binding equilibria and kinetics	MIT Press Chap 2.1-2.4	Dr. Yuk	Problem Set 2 Due	50/130
Tu	16-Feb	8	Central dogma of molecular biology	Ch 4 (Schuler et al)	Dr. Yuk		
Th	18-Feb	9	Genetic/metabolic regulation	Ch 5 (Schuler et al)	Dr. Yuk		
M	22-Feb	10	Recombinant DNA technology / Heterologous protein expression	Ch 8 (Schuler et al)	Dr. Yuk	Problem Set 3 Due	50/180
F	26-Feb	11	Protein engineering	Li, C. et al (Article)	Dr. Yuk		
Tu	2-Mar	12	Metabolic engineering	Varma, A et al (Article)	Dr. Yuk	Discussion Grade 2	30/210
Th	4-Mar	13	WPR I		Dr. Yuk	WPR 1	200/410
			Block II: Cellular Considerations				
Tu	8-Mar	14	General concepts of cell growth - Part 1	Ch 6.1 (Schuler et al)	Dr. Yuk		
F	12-Mar	15	General concepts of cell growth - Part 2	Ch 6.2-6.4 (Schuler et al)	Dr. Yuk		
Tu	16-Mar	16	General concepts of cell growth - Part 3	Ch 7 (Schuler et al)	Dr. Yuk	Problem Set 4 Due	50/460
Th	18-Mar	17	Operational Considerations for Bioreactors: Suspension and Immobolized Cultures	Ch 9.1-9.3 (Schuler et al)	Dr. Yuk	Discussion Grade 3	30/490
M	22-Mar	18	Bioreactor selection, scale-up and process control Part 1	Ch 9.4-10.1 (Schuler et al)	Dr. Yuk		
F	26-Mar	19	Bioreactor selection, scale-up and process control Part 2	Ch 10.2-10.4 (Schuler et al)	Dr. Yuk	Problem Set 5 Due	50/540
W	31-Mar	20	Upstream operational challenges and other biomanufacturing considerations		rofessor DeLisa		
F	2-Apr	21	Guest Lecture - Erin Johnson (MERK) Up Stream Processing		Erin Johnson		
F	9-Apr	22	WPR II		Dr. Yuk	WPR 2	200/740
			Block III: Downstream Considerations				
Tu	13-Apr	23	Product recovery and separation - Part 1	Ch 11.1-11.3 (Schuler et al)	Dr. Yuk		
Th	15-Apr	24	Product recovery and separation Part 2	Ch 11.4-11.7 (Schuler et al)	Dr. Yuk		
M	19-Apr	25	Bio Process Considerations using Animal Cells	Ch 12 (Schuler et al)	Dr. Yuk	Discussion Grade 4	30/770
Th	22-Apr	26	Bio Process Considerations using Plant Cells	Ch 13 (Schuler et al)	Dr. Yuk		
M	26-Apr	27	Medical Applications of Bioprocess Engineering	Ch 15 (Schuler et al)	Dr. Yuk		
F	30-Apr	28	Traditional Industrial Bioprocesses	Appendix A (Schuler et al)	Dr. Yuk	Discussion Grade 5	30/800
Tu	4-May	29	Capstone Presentations		Dr. Yuk	Capstone Paper	200/1000
M	10-May	30	Cadet Presentations		Dr. Yuk	Capstone Presentation	100/1100
			TEE Week of 12-15 DEC 2021			TOTAL POINTS	1100

PS's	250
WPR's	400
DG's	150
Paper	200
Pres	100
TOTAL	1100

CH350 Detailed Overview

- **Textbook:**
  1. *Bioprocess Engineering Basic Concepts,* 3rd Ed., by Michael L. Shulter, Fikret Kargi, Matthew DeLisa, Prentice Hall.
  2. *Quantitative Fundamentals of Molecular and Cellular Bioengineering,* by K. Dane Wittrup, Brice Tidor, Benjamin J. Hackel, and Casim A. Sarkar, The MIT Press.

- **Major Blocks:**
  1. Biomolecular considerations: enzyme kinetics and molecular biology
  2. Cellular considerations: cell growths and process considerations of bioreactor development
  3. Downstream considerations: bioprocess development in different cell cultures

CH350: Introduction to Bioengineering

Course Director: Dr. Simuck Yuk

Course Supervisor: COL Burpo

Credit Hours: 3.0 (BS=0, ET=3.0, MA=0)
Prerequisites:
Co-requisite: None
Lessons: 30 @ 75 min
Special Requirements: None

The purpose of this course is to provide the introductory knowledge for understanding the biotechnology/bioprocessing engineering. Topic includes enzyme kinetics, molecular biology, cell growth, bioreactors, and bioprocesses. The bioprocess control and its application to different biological systems are covered in the classroom instruction. An important emphasis is made on the use of kinetics and process controls on the biological systems for engineering application.

Topics – by Chapter

Bioprocess Engineering Basic Concepts, 3rd Ed., by Michael L. Shulter, Fikret Kargi, Matthew DeLisa, Prentice Hall.

Quantitative Fundamentals of Molecular and Cellular Bioengineering, by K. Dane Wittrup, Brice Tidor, Benjamin J. Hackel, and Casim A. Sarkar, The MIT Press.

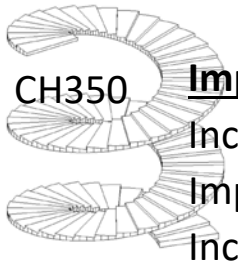
- Introduction
- Enzyme Kinetics
- Central Dogma to Molecular Biology
- Cell Growth
- Bioreactor Selection
- Bioprocess Consideration

Course Assessment – Items from Section III

Sustain:

Continue to use of DeLisa (3rd Ed.)

Continue to introduce problem demos



Improve:

Increase number of in-class problem demos.

Improve problem sets and WRPs.

Increase number of coding-related problems.

Assessment – Graded Events

1 *Capstone Presentation	100	9%
1 *Capstone Paper	200	18%
2 *WPRs	400	36%
5 Problem Sets(50pts/ea.)	250	23%
1 *Discussion	150	14%
Total:	1100	100.00%

CH300: Introduction to Biomedical Engineering

Course Director: COL Burpo

Course OIC: MAJ Jeffrey Chin

Credit Hours: 3.0 (BS=0, ET=3.0, MA=0)
Prerequisites: CH102, MA205
Co-requisite: None
Lessons: 30 @ 75 min
Special Requirements: None

This course provides a basis for understanding the application of engineering principles to problems in medicine and biology. It provides preparation for future graduate work in medical school, biomedical engineering, and chemical engineering. Specifically, the objectives of the course are: (1) to provide an introduction to the field and how it relates to other fields of engineering and science, (2) the develop the ability to apply mathematics, science, and engineering to solve problems, (3) to develop an understanding of the impact of engineering solutions on the medical field and society as a whole, and (4) to understand current topics within the field.

Assessment – Graded Events

6 *HWs@ 50 pts each	300	21.4%
2 *WPRs @ 200 pts each:	400	28.6%
1 *Capstone	200	14.3%
1 *TEE	500	35.7%
Total:	1400	
*Individual Points :	1400	100%

TEXT: Biomedical Engineering, 2nd Edition, by W. Mark Saltzman; Cambridge University Press, 2015.

COA 1

Block I: Molecular and cellular principles

- Biomolecular principles (Ch. 2)
- Biomolecular principles: Nucleic acids (Ch. 3)
- Biomolecular principles: proteins (Ch. 4)
- Cellular principles (Ch. 5)

Block II: Physiological principles

- Communication systems in the body (Ch. 6)
- Engineering balances: respiration and digestion (Ch. 7)
- Circulation (Ch. 8)
- Removal of molecules from the body (Ch. 9)

COA 2

Block I: Molecular and cellular principles

- Biomolecular principles (Ch. 2)
- Biomolecular principles: Nucleic acids (Ch. 3)
- Biomolecular principles: proteins (Ch. 4)
- Cellular principles (Ch. 5)

Block II: Physiological principles

- Communication systems in the body (Ch. 6)
- Engineering balances: respiration and digestion (Ch. 7)
- Circulation (Ch. 8)
- Removal of molecules from the body (Ch. 9)

Block III: Biomedical Engineering

- Biomechanics (Ch. 10)
- Bioinstrumentation (Ch. 11)
- Bioimaging (Ch. 12)
- Biomolecular Engineering I: Biotechnology (Ch. 13)
- Biomolecular Engineering II: Engineering of Immunity (Ch. 14)

CH450: Bioengineering Modeling and Analysis

Course Director: COL John Burpo

Credit Hours: 3.0 (BS=0, ET=3.0, MA=0)
Prerequisites: CH102, MA205
Co-requisite: None
Lessons: 30 @ 75 min
Special Requirements: None

This course provides a broad understanding of bioengineering disciplines to include biomechanics, biomaterials, tissue engineering, biocatalysis, biochemical engineering, and biosensors. Fundamental concepts of molecular kinetics, thermodynamics, and mass transport are applied in problem sets in each bioengineering sub-discipline and capstone design project providing students the opportunity for modeling, analysis, and design from the biomolecular to physiological length scale and across multiple time scales. Modeling software such as MATLAB and Mathematica is extensively used.

Topics – by Chapter

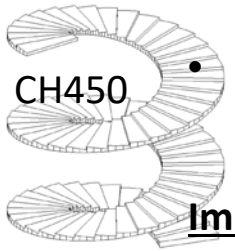
TEXT: Introduction to Biomedical Engineering, 3rd Edition, by John Enderle and Joseph Bronzino; Academic Press, 2012.

- Part I: Biomechanics (Ch. 1 and 4)
- Part II: Biomaterials (Ch. 5)
- Part III: Tissue Engineering (Ch. 6)
- Part IV: Biomedical Enzyme Kinetics (Ch. 7 and 8)
- Part V: Biochemical Engineering (Handouts)
- Part VI: Biosensors (Ch. 10)

Course Assessment – Items from Section III

Sustain:

- Best looking Dept Head/ CD/ Prof at the academy
- Strong instructor personal experience in mathematics, engineering, and chemistry
- Each lesson considers interdisciplinary science and engineering topics –science topics are taught in context of engineering applications



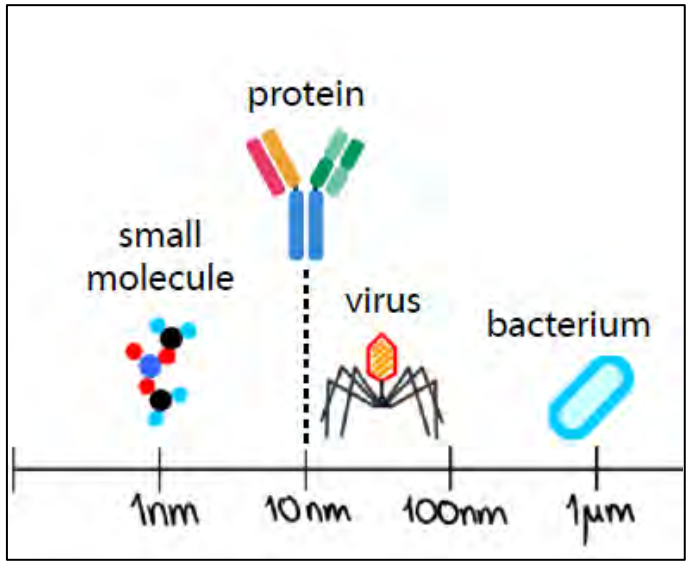
Improve:

Assessment – Graded Events

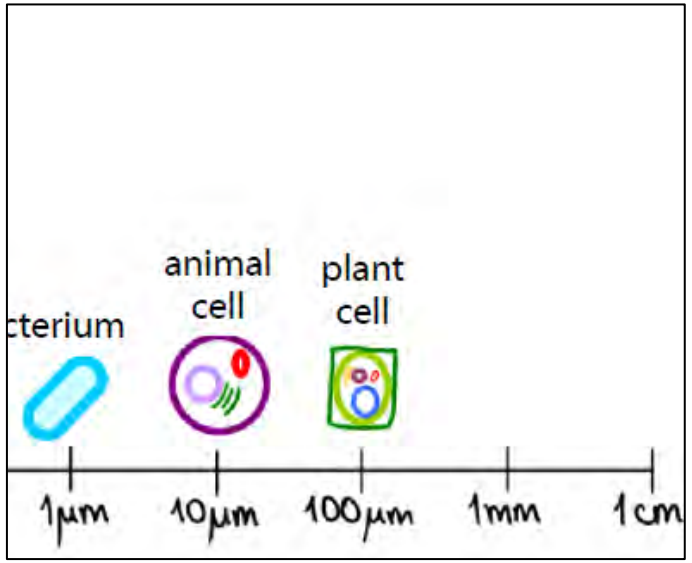
5 *Problem Sets@ 25 pts each	500	47.2%
6 *Quizes @ 200 pts each:	180	17.0%
1 *Paper	150	14.1%
1 *Presentation	50	4.7%
6 *Discussion	180	17.0%
Total:	1060	
*Individual Points :	1060	100%

CH350 Updates

Molecular Scale



Cellular Scale



- Finished with the block 1/2 and on-going with the block 3 of CH350.
- Cadets were introduced to both quantitative and qualitative perspectives of bioprocess engineering:
  1) Qualitative:
     a. Cell types (animal vs. plant)
     b. Central dogma of molecular biology
     c. Metabolic pathways and regulations
  2) Quantitative:
     a. Enzyme kinetics
     b. Mass transfer at immobilized enzymes
     c. Material balances on bioreactors
- Mathematica and excel were utilized to develop governing models for enzyme kinetic description and reactor designs.
- The block 1 was ended with WPR #1.
- The block 2 was ended with guest lectures and WPR #2.
- Curriculum memo to add CH350 permanently to REDBOOK.
- Assessment data to reinforce the memo.
- Dr. Biaglow/Dr. Yuk spearheading this effort JAN22.

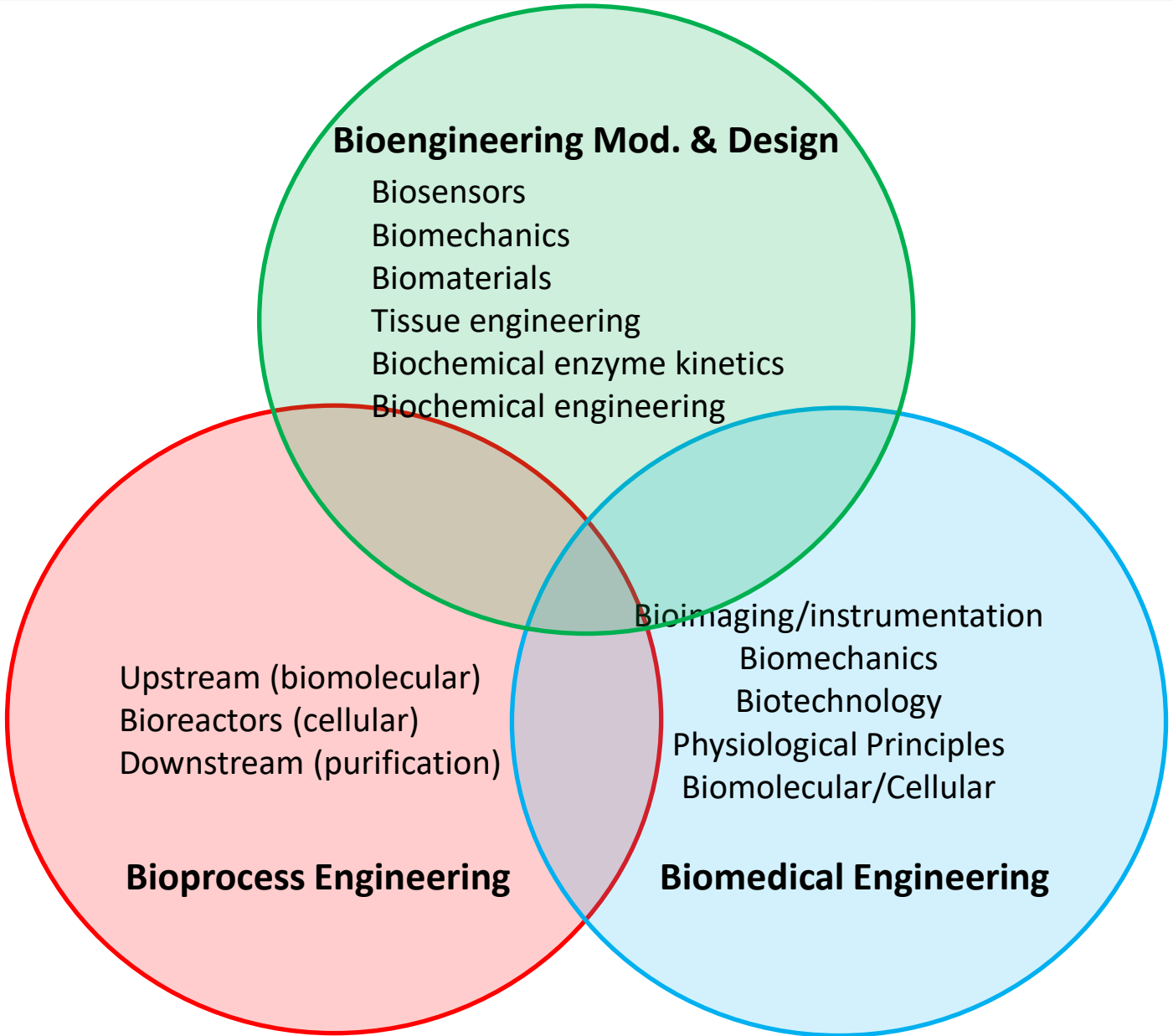
CH300 Updates

- Majority of block 1 of CH350 will be moved into the block 1 and 2 of CH300:
  a) Molecular description of cells (animal vs. plant)
  b) Central dogma of molecular biology (DNA, RNA, protein, etc)
  c) Genetic engineering
  d) Enzyme functionality and inhibitions
  e) Metabolic pathways (respiration and digestion)
- Block 3 will be focused on biomedical engineering application.
- Suggesting that concepts related to enzyme kinetics (especially quantitative perspective) and metabolic pathways to be reintroduced in CH350.
- Curriculum memo to add CH300 permanently to REDBOOK.
- Assessment data to reinforce the memo.
- Dr. Biaglow/Dr. Yuk spearheading this effort JUN22.

Bio-engineering Track/Sequence/minor

COA 1	COA 2	COA 3
CH362-CH364-CH450	**CH300-CH350-CH450**	**CH362-CH350-CH450**
Will require minimum of 2 additional faculty (if new sections added)	Will require additional faculty, minimum of 2. Ongoing AP searches. Faculty allocation will be the same in either COA, so use new faculty to develop new courses.	Will require additional faculty, minimum of 1. Ongoing AP searches. Faculty allocation will be the same in either COA, so use new faculty to develop new courses.
Does not give Chem E cadets new electives.	*Chem E cadets currently have no electives in DCLS. Continuing area of concern.* Chem E cadets get 3x elective courses.	*Chem E cadets currently have no electives in DCLS. Continuing area of concern.* Chem E cadets get 2x elective courses.
Existing course material/objectives are tied to ABET outcomes. These courses are highly optimized for chemical engineering content leading to high performance in these areas. Will require extensive re-configuring of **two** key program courses for a different audience without basis in assessment; max. 2 sections	Courses should be designed to meet student needs. Memo constructed in AY18 was reviewed by other programs and is ready to drop now. Even if proposed courses are not optimal or we do not agree on content, get the courses in Redbook.	Courses should be designed to meet student needs. Memo constructed in AY18 was reviewed by other programs and is ready to drop now. Even if proposed courses are not optimal or we do not agree on content, get the courses in Redbook.
Less resource encumbered	Better for the department. Opportunity for interdisciplinary collaboration and team building.	Better for the department. Opportunity for interdisciplinary collaboration and team building.
Course material/objectives tied to ABET outcomes 1-7,8		
Cannot dilute or alter content		

COA2 - Bioengineering Venn Diagram



Legend
- CH450
- CH350
- CH300

Bio-engineering Track

- Select Bioengineering AP…ongoing Fall 2020
- Select Bioengineering T10 ✓
- QA/QC 3.0 ET credit for CH450 ✓
- Stand up new courses…CH350 & CH300 ✓
- Get to curriculum committee…*Dr. Biaglow is the OIC for this effort*
- Get courses in Redbook
- Get Bioengineering sequence approved
- ABET-compatibility (minor point)

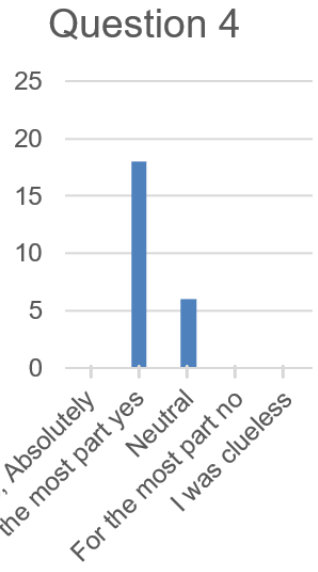
FEE Program Data

As of 15APR Class of 2021: 75% passing FEE first time

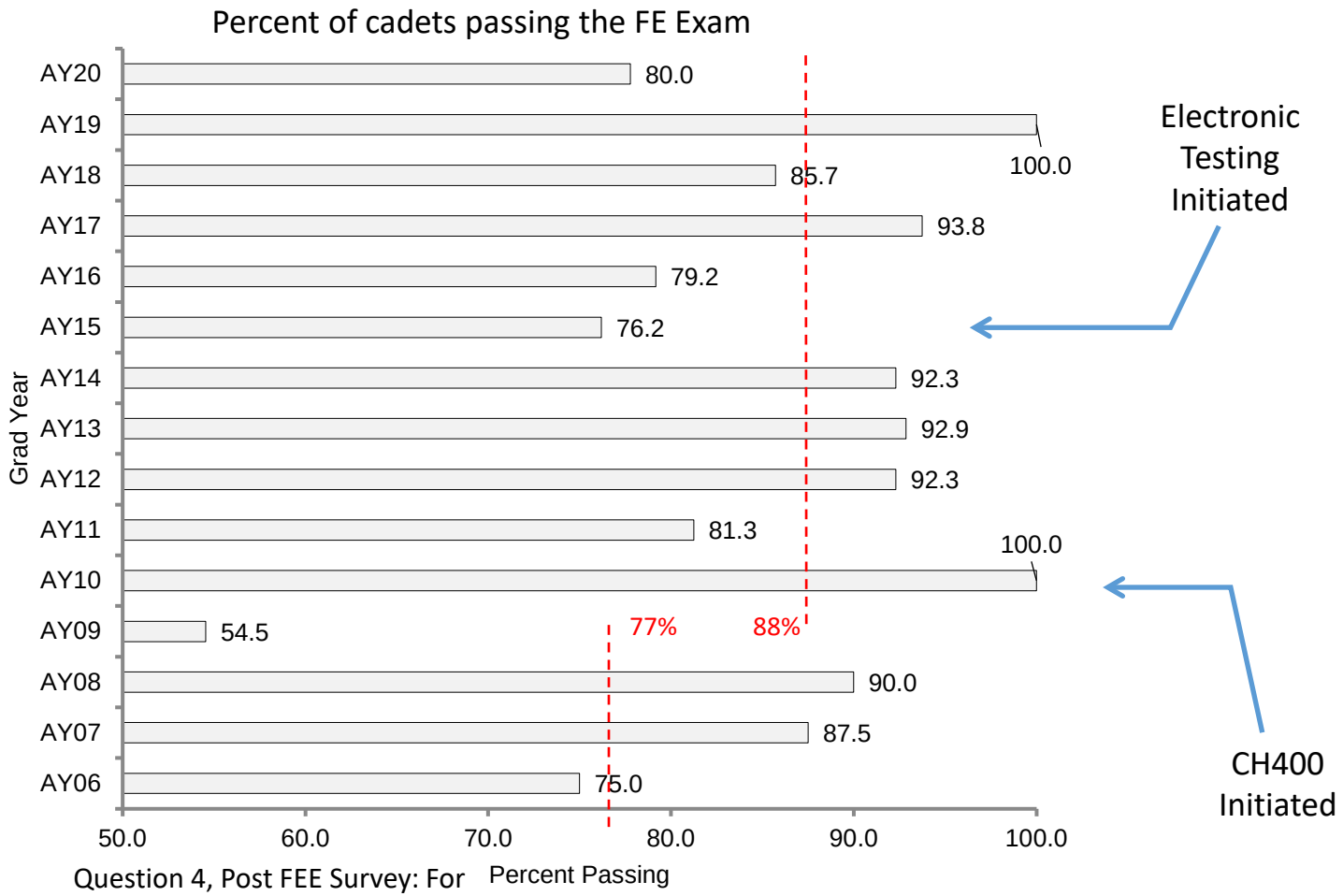
Student Outcome 7: Acquire and apply new knowledge as needed, using appropriate learning strategies

National, (+/- ~1%):

2020	74.6%
2019	77.0%
2018	75.0%
2017	74.0%
2016	79.0%
2015	77.4%
---	---
2014	89.0%
2013	86.3%
2012	85.1%
2011	87.0%
2010	87.0%
2009	84.0%
2008	87.0%
2007	87.0%
2006	87.0%

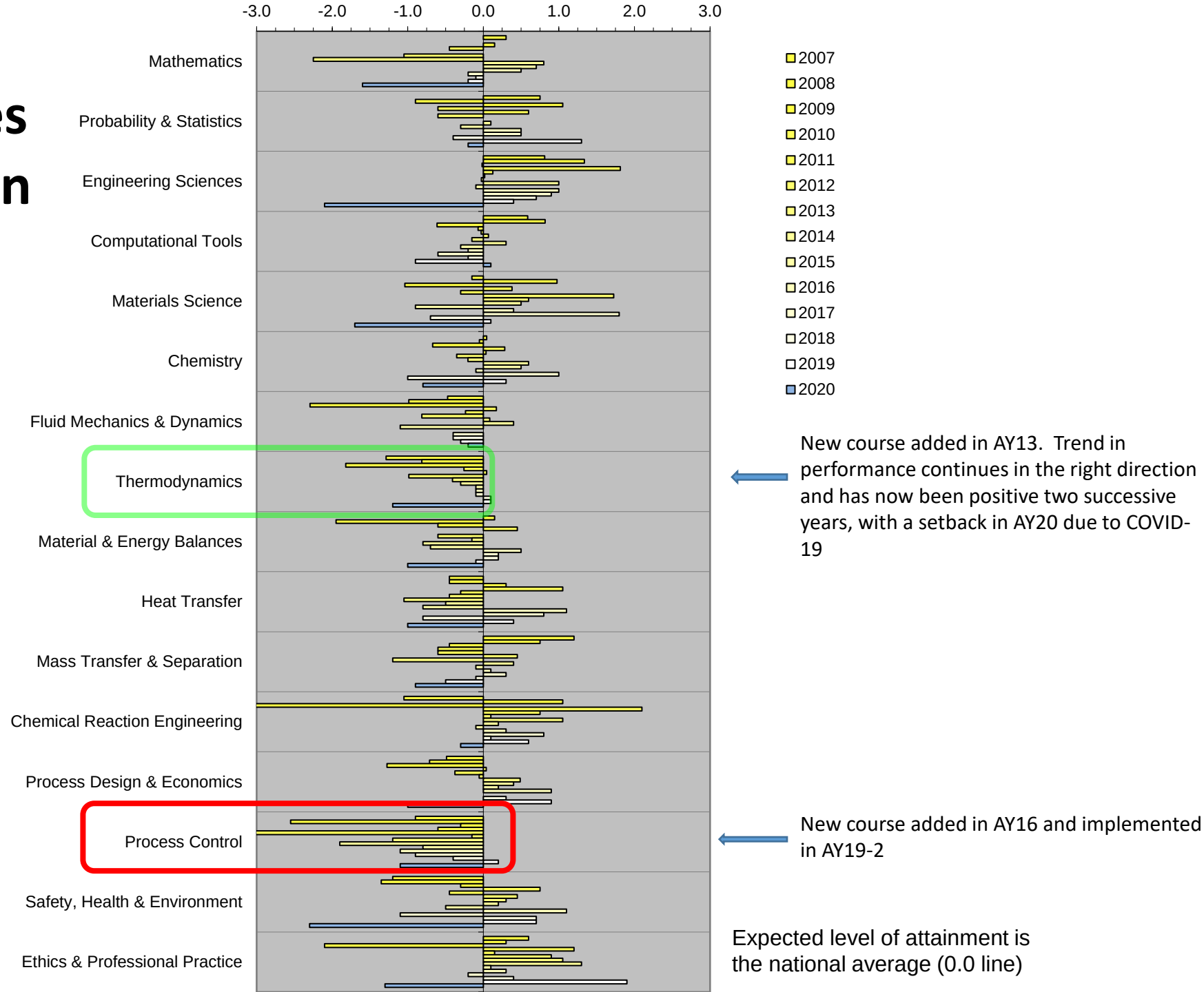


Question 4, Post FEE Survey: For the questions on the exam that seemed new to you, were you able to learn the material on the spot?



Topical Outcomes Evaluation

Deviations from National Averages AY07 to AY20



New course added in AY13. Trend in performance continues in the right direction and has now been positive two successive years, with a setback in AY20 due to COVID-19

New course added in AY16 and implemented in AY19-2

Expected level of attainment is the national average (0.0 line)

Program Mission

The mission of the chemical engineering program is to prepare commissioned leaders of character who are proficient in applying chemical and engineering principles to solve problems in a complex operational environment.

ABET | Engineering Technology Accreditation Commission

Accredited 1 October 2012 to present

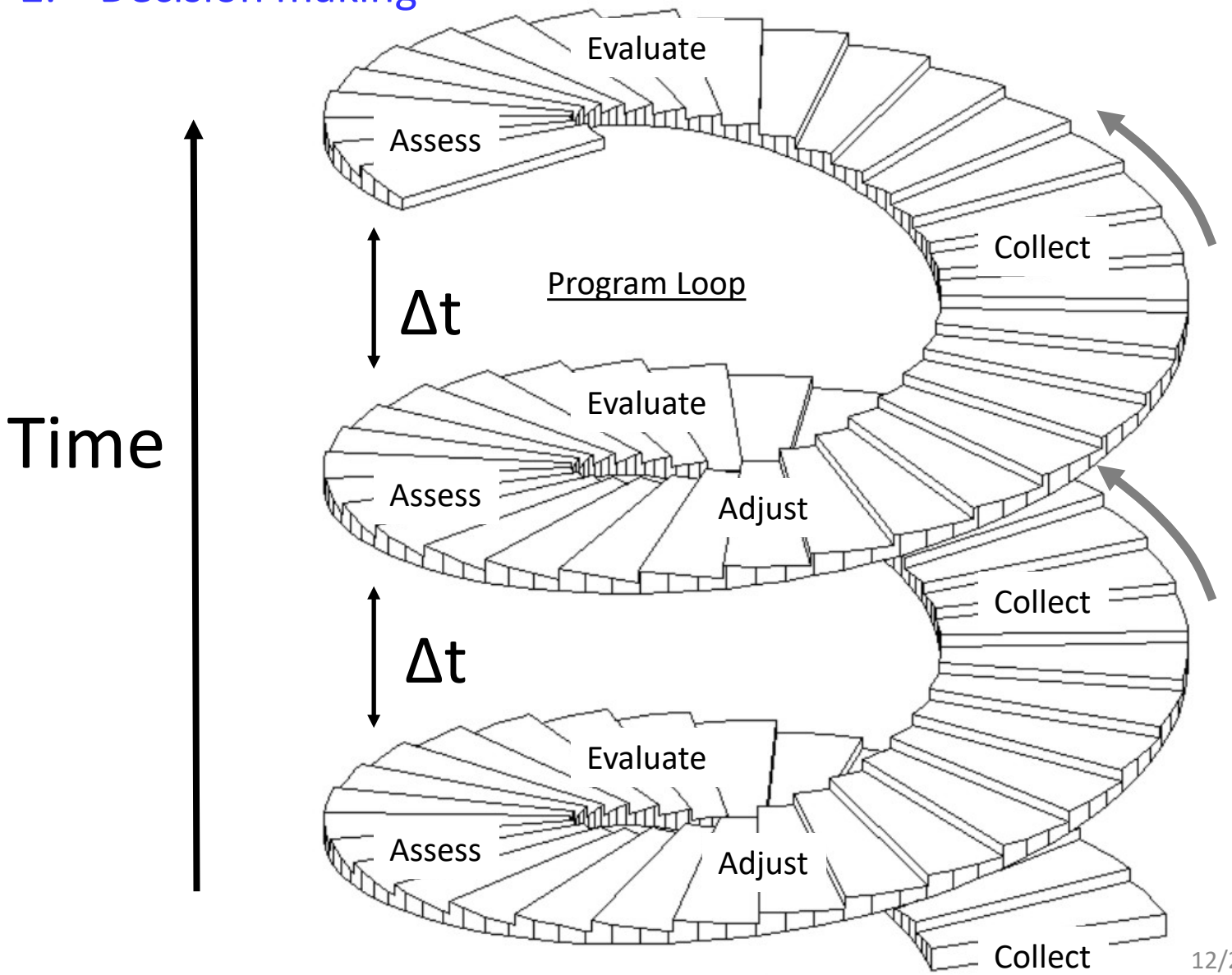
Next Record Year: AY20

Next ABET Visit: Fall 2020 (AY21-1)

Data used to support:

1. Assessment
2. Decision making

Program Assessment Cycle



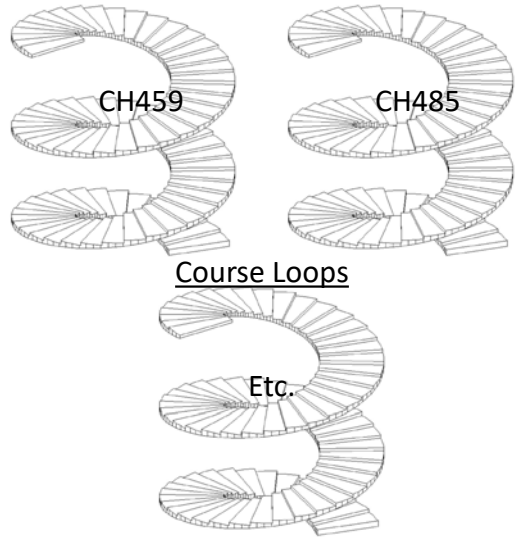
Performance Indicators:

1. FE Exam Results
2. Coursework Embedded Indicators
3. Surveys (Cadet, Faculty, Adv. Board)
4. Course Grades

Program-level

Course-level

Course Assessments (Sect. III)
Embedded Indicators



*Student Outcomes

Identical to ABET 1-7 plus one additional outcome (8)

On completion of the chemical engineering program, our graduates will be able to:	
1.	Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2.	Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3.	Communicate effectively with a range of audiences.
4.	Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5.	Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6.	Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7.	Acquire and apply new knowledge as needed, using appropriate learning strategies.
8.	Understand the chemical engineering curriculum, including chemistry, material and energy balances, safety and environmental factors, thermodynamics of physical and chemical equilibria, heat, mass, and momentum transfer, chemical reaction engineering, continuous and staged separation processes, process dynamics and control, modern experimental and computing techniques, and process design.

Performance Indicators

- Coursework embedded indicators (example to be shown)
- Cadet end-of-semester surveys
- FE Exam results
- Cadet grades in program courses
- Advisory Board student outcome surveys
- Faculty student outcome surveys

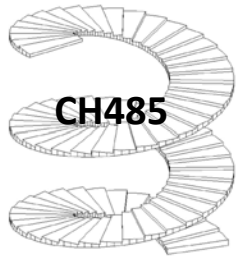
Course Assessment Cycle

- Published guidance in CD Handbook
- Required for all chemical engineering courses used for assessment (not optional)
- Similar system for courses outside department

Table 4-1. Outline of the course assessment process

Description	Assessment	Recommendations
SECTION I. COURSE DESCRIPTION: This section summarizes the course, exactly as it was taught in the most recently completed semester.	SECTION II. COURSE ASSESSMENT - This section provides data and analysis to answer the following questions:	SECTION III. RECOMMENDED CHANGES – All proposed changes to the course, in each of the specified areas. Recommendations should be based on assessments from Section II.
1. Redbook Description - List the current Redbook description.	1. Redbook Description - Does the Redbook description match what is taught in the course?	1. Redbook Description- For changes, include a cut and paste Redbook entry and use "track changes" when submitting recommendation.
2. Enrollment - This AY and next AY (projected)	2. Enrollment - How does the student population compare from one year to the other? Assess effect of population on course.	2. Enrollment - Recommended teaching style considerations associated with the student population.
3. Course Content - Abbreviated list of subjects or lesson blocks covered in the course (not the syllabus).	3. Course Content - Is the course content appropriate?	3. Course Content - Recommended changes to course content.
4. Course Objectives - List course objectives here.	4. Course Objectives - Were the course objectives achieved? Do the course objectives cover the body of knowledge appropriately? Do the course objectives lend themselves to assessment?	4. Course Objectives - Recommended changes to objectives.
	4a. Coverage - Indicate coverage of objectives by graded events.	4a. Coverage – Recommended changes to coverage of objectives by graded events.
	4b. Performance - Indicate performance on course objectives.	4b. Performance - Recommendations to address shortcomings in performance on course objectives.
5. Survey Questions - List web-based and any other survey questions administered to cadets (if used).	5. Survey Questions - Are the survey questions appropriate?	5. Survey Questions - Recommended changes to survey questions.
Examples include course questions, program questions, and USMA web-based survey questions.	5a. Survey Results – Include analysis of Course-End Feedback or other surveys to include significant trends, suggestions or input that you believe should be incorporated into the course in the future.	5a. Survey Results – Recommendations to address any shortcomings identified by survey results (if necessary).
	5b. Survey Freeform Comments – (If used.) Results of any free-form comments from cadets about the course – summarize the most prevalent positive and negative comments.	5b. Survey Freeform Comments - Recommendations to address shortcomings identified from free-form comments, if necessary.
6. Course GPA - List course GPA here. Include numbers from the last six terms.	6. Course QPA – Discuss any discernible trends or abrupt changes in course GPA over past several terms.	6. Course QPA – Recommendations to address any perceived problems.
7. TEE Grade - List course TEE grade here from the last six terms.	7. TEE Grade – Discuss any discernible trends or abrupt changes in TEE grade over past several terms.	7. TEE Grade – Recommendations to address concerns with TEE grades.
8. Course Processes	8. Course Processes	8. Course Process
8a. Textbook - Title, author, and edition	8a. Textbook - Is the current textbook appropriate?	8a. Textbook - Recommended changes to textbook.
8b. Lessons and Labs - List of lessons and labs in the course (syllabus).	8b. Lessons and labs - Are the number of lessons and labs appropriate?	8b. List of lessons and labs - Recommended changes to the number of lessons and labs.
8c. Summary of Graded Requirements - Number, type, and weight of drill problems, Problem Sets, Special Problems, EOP's, Lab Reports, Writs, WPR's, TEE, and Instructor Grade (as applicable).	8c. Summary of Graded Requirements - Are the graded requirements appropriate?	8c. Summary of Graded Requirements - Recommended changes to the graded requirements.
8d. Areas of Special Emphasis - Any special topics not included in the Redbook description or program embedded indicators go here.	8d. Areas of Special Emphasis - Are the areas of special emphasis appropriate?	8d. Areas of Special Emphasis - Recommended changes to the areas of special emphasis.
9. Contribution to Student Outcomes - List student outcomes here.	9. Contribution to the Student Outcomes - Does the course contribute to the student outcomes? How?	9. Contribution to Student Outcomes
	9a. Coverage - Indicate coverage of objectives by graded events.	9a. Coverage - Recommendations to address shortcomings in coverage of outcomes.
	9b. Performance - Indicate performance on course objectives.	9b. Performance - Recommendations to address problems in performance on student outcomes.
10. Resources and Laboratories	10. Resources and Laboratories	10. Resources and Laboratories
10a. Laboratories - List laboratories lab projects used in the course.	10a. Laboratories - Was equipment available for desired experiments? Was equipment working?	10a. Laboratories - Recommendations to address any shortcomings in equipment.
10b. Computer Labs - List computer labs used in the course.	10b. Computer Labs - Were adequate computing facilities available for the course?	10b. Computer Labs - Recommendations to improve computing facilities.
10c. Physical Models & Demos - List physical models and demos used in the course.	10c. Physical Models & Demos - Were physical models and demos adequate? In good working order?	10c. Physical Models & Demos - Recommendations for new demos or models, or to improve condition of existing models and demos.
10d. Technician Support - List technician support used in this course (wet lab or IT).	10d. Technician Support - Was technician support adequate?	10d. Technician Support - Recommendations to improve technician support.
10e. Supplies - List any wet lab or computer supplies used in this course.	10e. Supplies - Were supplies adequate?	10e. Supplies - Recommend additional supplies for this course.
10f. Additional Facilities - List any additional facilities used.	10f. Additional Facilities - Were the additional facilities adequate?	10f. Additional Facilities - Recommendations to address perceived shortcomings in additional facilities?
10g. Unfunded Requests - List any unfunded requests from last AY and whether or not they were funded.	10g. Unfunded Requests - If provided, were the items made available by the unfunded requirements adequate?	10g. Unfunded Requests - Recommendations for any additional unfunded requirements.
11. Recommendations from last AY - List recommendations from last year's course assessment and describe how they were implemented this AY. Go item by item from 1 through 10f.		

- Sustain and improve from last AY



Example Schedule for Chemical Engineering Classes of 20xx and Beyond

Fall Term	Course	Credit Hours	Spring Term	Course	Credit Hours
4th CLASS					
MA103	Math. Modeling & Intro. Calculus	4.5	MA104	Calculus I	4.5
CH101	General Chemistry I	4.0	CH102	General Chemistry II	4.0
EN101	Composition	3.0	EN102	Literature	3.0
HI107	Western Civilization	3.0	HI108	Regional Studies in World History	3.0
IT105	Introduction to Computing & IT	3.0	PL100	General Psychology	3.0
PE11x	Combatives / Boxing / Movement	0.5	MS100	Introduction to Warfighting	1.5
			PE150	Fundamentals/Personal Fitness	1.5
3rd CLASS		Total 18.0			Total 20.5
MA205	Calculus II	4.0	*CH362*	*Mass and Energy Balances*	*3.5*
PH205	Physics I	4.0	*MA364*	*Applied Engineering Math*	*3.0*
Lx203	Foreign Language	4.0	PH206	Physics II	4.0
SS201	Economics	3.0	Lx204	Foreign Language	4.0
PY201	Philosophy	3.0	SS202	American Politics	3.0
MS200	Fundamentals: Army Operations	1.5	EV203	Physical Geography	3.0
			PE 2xx	Lifetime Physical Activity	0.5
2nd CLASS		Total 19.5			Total 21.0
CH363	*Separation Processes*	*3.5*	*CH364*	*Chemical Reaction Engineering*	*3.5*
EE301	*Fundamentals of Electrical Engineering*	*3.5*	*CH367*	*Introduction to Automatic Process Control*	*3.0*
CH383	*Organic Chemistry 1*	*3.5*	*MC312*	*Thermal-Fluid Systems 2*	*3.0*
MC311	*Thermal-Fluid Systems 1*	*3.5*	*Elective*	*Engineering Elective 1*	*3.0*
PL300	Military Leadership	3.0	SS307	International Relations	3.0
MA206	Probability and Statistics	3.0	MS300	Platoon Operations	1.5
PE32x	Survival Swimming	0.5	PE360	Combat Applications	1.5
1st CLASS		Total 20.5			Total 18.5
CH459	*Chemical Engineering Laboratory*	*3.5*	*CH402*	*Chemical Engineering Process Design 2*	*3.5*
CH365	*Chemical Engineering Thermodynamics*	*3.0*	*CH400*	*Chemical Engineering Prof. Practice*	*3.0*
CH485	*Heat & Mass Transfer*	*3.5*	*Elective*	*Engineering Elective 3*	*3.0*
CH401	*Chemical Engineering Process Design 1*	*3.5*	HI302	History of the Military Art	3.0
Elective	*Engineering Elective 2*	*3.0*	LW403	Constitutional & Military Law	3.0
PE450	Army Fitness Development	1.5	MX400	Officership	3.0
		Total 18.0			Total 18.5

Required Courses * (for classes 2020 and beyond)	
MA364	Engineering Mathematics
CH362	Mass & Energy Balances
CH363	Separation Processes
CH364	Chemical Reaction Engineering
CH367	Introduction to Automatic Process Control (XE472 2019 and previous)
CH485	Heat & Mass Transfer
CH459	Chemical Engineering Laboratory
CH402	Chemical Engineering Process Design
CH400	Professional Practice
MC311	Thermal-Fluid Systems I
MC312	Thermal-Fluid Systems II
EE301	Fundamentals of Electrical Engineering
MC300	Fundamentals of Engineering Mechanics & Design (Statics & Dynamics)
CH365	Chemical Engineering Thermodynamics
CH383	Organic Chemistry 1

***Not including prerequisites**

Chemical Engineering Student Outcomes

On completion of the chemical engineering program, our graduates demonstrate an ability to

1. Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

2. Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

3. Communicate effectively with a range of audiences.

4. Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

5. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

6. Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

7. Acquire and apply new knowledge as needed, using appropriate learning strategies.

8. Understand the chemical engineering curriculum, including:
    - Chemistry,
    - Material and energy balances,
    - Safety and environmental factors,
    - Thermodynamics of physical and chemical equilibria,
    - Heat, mass, and momentum transfer,
    - Chemical reaction engineering,
    - Continuous and staged separation processes
    - Process dynamics and control,
    - Modern experimental and computing techniques, and
    - Process design.

Chemical Engineering Program Objectives

During a career as commissioned officers in the United States Army and beyond, program graduates:

- Contribute to the solution of infrastructure or operational problems in a complex operational environment.
- Succeed in graduate school or other advanced study programs.
- Advance their careers through clear and precise technical communication.
- Demonstrate effective leadership and chemical engineering expertise.

Chemical Engineering Program Population