



DEPARTMENT OF THE ARMY  
**UNITED STATES MILITARY ACADEMY**  
West Point, New York 10996

**REPLY TO  
ATTENTION OF  
MADN-CLS**

28 August 2023

MEMORANDUM THRU COL Corey M. James, Acting Department Head, Department of Chemistry and Life Science, United States Military Academy, West Point, NY 10996

FOR Dean of the Academic Board, United States Military Academy, West Point, NY 10996

SUBJECT: 2023 Executive Summary of Chemical Engineering (CEN1) Program Assessment

1. This memorandum is an executive summary, per *DPOM 5-07 Assessing and Improving Student Learning in the Academic Program*, outlining the changes in the Chemical Engineering Program's assessment and assessment process, as well as curriculum changes, that have occurred since the last executive summary in September 2022, in response to program assessment.

a. Course proposals for chemical engineering electives CH300, Biomedical Engineering and CH350, Bioprocess Engineering were unanimously approved by the Curriculum Committee and General Committee to be permanent USMA Redbook offerings. The Chemical Engineering Program submitted CH300 and CH350 syllabi, course content, major graded events to the USMA ABET Committee for engineering topics credit hour review. The course materials for CH300 are currently under review by the Committee to assess its engineering topic credit. Both CH300 and CH350 have been taught in AY22 as pilot courses and the second iteration was completed in AY23.

(1) A curricular change in our program in AY23 was moving the Writing in the Major (WiM) requirement for cadets majoring in CEN1 and Chemical Engineering Studies (CES1) requirement to CH459 Chemical Engineering Laboratory course, and to CH365 Chemical Engineering Thermodynamics, respectively. Previously, the WiM requirement for CEN1 cadets was completed in MC312 Thermal-Fluid-Systems II. However, the WiM requirement for mechanical engineering (MEN2) has been moved from MC312 to ME400. Since CEN1 cadets will not be taking ME400, this proposal requested moving the WiM requirement to CH459 Chemical Engineering Laboratory course, and for CES1 to CH365 Chemical Engineering Thermodynamics. This change was approved and in progress for the Class of 2024 in CH459 AY24-1 .

(2) The standard 8TAP that reflects the curriculum is shown in the attached document "Encl 1 - exsum\_CEN1\_2023\_08 - 8TAP".

b. Student Learning Outcomes (SLO) or Student Outcomes (SO) Assessment. The Chemical Engineering Major (CEN1) contains program elements recommended by

ABET as Student Outcome (SO) 1-7, +8 (program criterion as SO8) which are for this executive summary are synonymous to SLOs 1-7, +8 as shown in the “Encl 2 - exsum\_CEN1\_2023\_08 - Program Student Outcomes”.

(1) For AY23, the Chemical Engineering Program continued to assess performance against the SOs required by ABET and implemented in AY19. The updated assessment process was fully described in the 2019 Executive Summary of the CEN1 Program and more fully described in the 2020 ABET Self-Study.

(2) The SO assessment process requires analysis of our assessment data pack, followed by discussions among faculty members, advisory board members, and students. The assessment data pack for AY23 is included in the attached document “Encl 3 - exsum\_CEN1\_2023 Assessment Data 2023\_08.” However, the assessment process is not complete until our advisory board meets after Spring Break in AY24-2 and will be submitted upon completion of our process. A completed assessment for AY22 with advisory board feedback is included as a reference in the attached document “Encl 4 - exsum\_CEN1\_2022 Assessment Data after Advisory Board\_2023\_08”. The advisory board table on page 22 was updated with the new survey data. Of note, the performance of cadets on the Fundamentals of Engineering Exam (FEE) during AY23 was lower than AY22 on the first attempt and overall. The first attempt passing rate was 61.5%. Two more chemical engineers passed the FEE on their second try for an overall 76.9% pass rate (10/13 Cadets Passed the FEE Overall) for Class of 2023 which is above this year’s national chemical engineering average pass rate of 70.2%. While we strive for a 100% pass rate, we are proud to have exceeded the national average in years prior that the program has been offered. As shown in “Encl 5 - exsum\_CEN1\_2023-08-FEE Results AY23”, the average FEE passing rate has been higher than the national average for eight years in a row and 11 out of the last 12 years.

(3) FE exam data for Student Outcome 8 (SO8) is shown in the attached document “Encl 5 – exsum\_CEN1\_2023-08-FEE Results AY23” (See page 2 and 3 of Encl 5 for FEE data comparison to previous years). The data shows an improvement this year in the Ethics & Professional Practice section compared to AY22 and almost one standard deviation higher than the national average. Additionally, cadets aggregated scores on Chemistry & Biology, Fluid Mechanics and Dynamics, Thermodynamics, Heat Transfer, and Chemical Reaction Engineering sections were very close to the national average. The cadet’s performance on Engineering Sciences, Economics, and Process Controls was almost one standard deviation below the national average. Moreover, the overall performance in Chemistry & Biology, Safety, Health, & Environment, Thermodynamics, and Heat Transfer are trending upward the last two years. Overall, the cadets performed closest to the national average in both Thermodynamics and Heat Transfer. The addition of CH365 in AY13 and CH367, Process Controls in AY19 demonstrates our assessment-based effort at program improvement.

(4) The remaining topics on the FE exam were generally within historical variations and/or standard deviations.

(5) During AY23 the program continued to utilize program-developed 1/0 rubrics to assist course directors in more precisely defining embedded indicators. Of significant note, all course directors completed this part of the program assessment correctly and on time. This saved considerable time in the preparation of the assessment data in Enclosure 3 - 2023 Assessment Data.

(6) We acknowledge lower than average scores shown in Enclosure 2 – 2023 Assessment Data for CH400, Chemical Engineering Professional Practice on Student Outcome 1 (SO1) and Student Outcome 4 (SO4). This course presents challenging homework and quiz problems to provide adequate FEE preparation for the first-class cadets (Firsties). The program has a high level of expectation in CH400 and therefore the scores of the graded events are slightly lower on average than our other chemical engineering courses. CH400 prepares Firsties for professional practice as chemical engineers, and combines the fundamental chemical engineering curriculum into a comprehensive course. We also acknowledge that the cadet surveys have also rated CH400 lower than other courses due to the difficulty of graded events, which we see as a positive result.

(7) The chemical engineering program addresses ethics and process safety separately for the purposes of assessment through Student Outcome 4 (SO4) and our Program Criterion (SO8), respectively. Standards and ethics are discussed throughout the curriculum in the core courses, CH400 and the capstone course, CH402 Chemical Engineering Process Design. The program addresses the hazards associated with chemical processes, and process safety education in the curriculum through CH459 and CH402. As shown in Enclosure 5 – FEE Results AY23, the cadets have outperformed the national average on the process safety aspects of the FEE as exemplified by the cadet's performance above the national average in Ethics & Professional Practice and very close to the national average on Safety, Health & Environment.

(8) The program continues to support the Academic Program Goals and the statements of What Graduates Can Do. The mapping between our SOs and the APG/WGCD statements is found in "Encl 6 – exsum\_CEN1\_2023-08 APG-WGCD Mapping". Numerical scores are included in the attachment. The scores are based on grades on embedded indicators on a 0-5 scale. Thus a 4 is 80%. In all cases, scores are above 4 and many are above 4.5. The program averages from Enclosure 3 – Assessment Data for all SOs (1-7) are mapped to indicators for specific APGs supporting their respective WGCDs.

c. Other than the stated change to the assessment process to reflect ABET accreditation criteria, there are no planned changes to the Chemical Engineering program's assessment process.

d. Assessment schedule. The program assessment process is currently in progress. The process is initiated during the summer of 2023 when the data assessment packet is distributed to faculty for analysis. Program assessment for AY23 will be complete by 1 July 2024 (following our next advisory board meeting, at which time the board will evaluate the program data of AY2022) and Enclosure 3 will be update at that time. The planned Advisory Board meeting for AY23 will occur in late April or early May 2024.

e. Our last ABET record year was AY19-20 with a remote onsite visit taking place 14-19 November 2020. Overall, the program passed with positive feedback on all aspects. The program strength was reported to be a focus process design and safety portion of the program and with the use of process simulators in the curriculum. We are actively preparing for the next ABET record year in AY25 with a focus on our current program assessment and the creation of two new elective courses in bioengineering for CEN1 majors.

f. We have examined the complimentary support courses and they do exactly what they should be doing which is providing foundational math and applied science framework. As shown in the end of semester survey response results from cadets, EE301, Fundamentals of Electrical Engineering had the lowest scores student survey feedback for SOs 1, 2, 5, 6, and 7. EE301 provides the basis for understanding of electronic circuits to aid chemical engineering process control modeling. As a program, we met with Electrical Engineering Program leadership and EE301 course leadership to discuss ways integrate more applicable examples into classes to better connect the course content to chemical engineering processes. Conversations continue between Chemical Engineering and Electrical Engineering faculty on ways to incorporate chemical engineering problems within course content. MA364/365, Engineering Mathematics, provides the basis and background of the advanced math skills required to master the chemical engineering curriculum moving forward. PH206/256 Physics II provides a deeper understanding of the mathematics and underlying science that is part of CEN1.

2. Point of contact for this action is the AY23 Chemical Engineering Program Director, Dr. Enoch A. Nagelli, at x3904.

6 Enclosures

1. Approved CEN1 8TAP
2. Program Student Outcomes
3. AY23 Assessment Process and Data
4. AY22 Assessment Process and Data
5. FEE Topical Outcomes Evaluation
6. APG-WGCD Mapping

ENOCH A. NAGELLI PH.D.

Associate Professor

Chemical Engineering Program Director (AY23)

**Enclosure 3 to 2023 Executive Summary of Chemical Engineering Program  
Assessment: Assessment Process and Data**

This document is a separate file entitled "Encl 3 - exsum\_CEN1\_2023 Assessment Data 2023\_08"

This file was published to the program on 26 August 2022. An updated file containing Faculty, Advisory Board, and Program Director survey data and input will be published o/a 1 June 2024.

**Enclosure 1 to 2023 Executive Summary of Chemical Engineering Program Assessment:**  
**Approved CEN1 8TAP**  
**CEN1 - Class of 2023**

4th Class Year Fall Term	Spring Term	3rd Class Year Fall Term	Spring Term	2nd Class Year Fall Term	Spring Term	1st Class Year Fall Term	Spring Term
<i>E</i> <b>MA103</b> 4.0	<i>E</i> <b>MA104</b> 4.5	<i>E</i> <b>MA205</b> 4.5	<i>R</i> <b>CH362</b> 3.5	<i>R</i> <b>CH363</b> 3.5	<i>R</i> <b>CH364</b> 3.5	<i>D,R</i> <b>CH459</b> 3.5	<b>CH402</b> 3.0
<b>EV203/ CH101</b> 4.0	<i>R</i> <b>CH101/ PH205</b> 4.0	<i>R</i> <b>PH205/ PH206</b> 4.0	<i>R/</i> <b>EV203/ PH206</b> 4.0	<i>R</i> <b>EE301</b> 3.5	<b>CH367</b> 3.0	<b>CH365</b> 3.0	<b>CH400</b> 1.5
		<i>R</i> <b>CH102</b> 4	<b>MA364/5</b> 3.0	<i>R</i> <b>CH383</b> 3.5			
<b>EN101</b> 3.0	<b>EN102</b> 3.0	<i>R</i> <b>CH102</b> 4	<b>MA364/5</b> 3.0	<i>R</i> <b>CH383</b> 3.5	<b>ME362</b> 3.5	<i>R</i> <b>CH485</b> 3.5	<b>Engr Elective</b> 3.0
<b>IT105</b> 3.0	<b>PL100</b> 3.0	<i>E</i> <b>DFL1</b> 4.0	<b>PY201</b> 3.0	<b>ME301</b> 3.5	<b>MC300</b> 3.0	<b>Engr Elective</b> 3.0	<b>LW403</b> 3.5
<b>HI105</b> 3.0	<b>HI108</b> 3.0	<i>R</i> <b>SS201</b> 3.5	<i>E</i> <b>DFL2</b> 4.0	<b>PL300</b> 3.0	<b>SS307</b> 3.5	<b>Engr Elective</b> 3.0	<i>R</i> <b>HI302</b> 3.0
			<i>R</i> <b>SS202</b> 3.5	<b>MA206</b> 3.0			<b>MX400</b> 3.0

*D* = Double blocked course

*R* = RSTU lab course

*E* = Meet every day for 55 minutes

	Course should not be moved from that year or term
	Course may be scheduled in the fall or spring of that academic year
	Complementary Support Courses
	Core Engineering Sequence (not applicable) Course
	3 Science Depth
	Course 9 STEM Depth
	other electives - most popular electives are templated

**Enclosure 2 to 2023 Executive Summary of Chemical Engineering Program Assessment:  
Approved CEN1 ABET Student Outcomes and Program Criterion  
CEN1 - Class of 2023**

The Chemical Engineering Major contains all the program elements recommended by ABET. To be consistent with our program assessment for the ABET accreditation process, **“Student Outcomes (SOs) (ABET 1-7, +8 as Program Criterion)” below are equivalent to the “Student Learning Outcomes (SLOs)” per DPOM 5-07 Assessing and Improving Student Learning in the Academic Program.** Graduates who complete a Chemical Engineering Major will be able to do the following:

- **Student Outcome 1 (SO1):** *Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.*
- **Student Outcome 2 (SO2):** *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.*
- **Student Outcome 3 (SO3):** Communicate effectively with a range of audiences.
- **Student Outcome 4 (SO4):** 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.
- **Student Outcome 5 (SO5):** Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- **Student Outcome 6 (SO6):** Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- **Student Outcome 7 (SO7):** Acquire and apply new knowledge as needed, using appropriate learning strategies.
- **Program Criterion (Student Outcome 8 - SO8):** The Chemical Engineering Program provides the graduate with a through grounding and working knowledge of:
  - a. Chemistry,
  - b. Material and energy balances,
  - c. Safety and environmental factors,
  - d. Thermodynamics of physical and chemical equilibria,
  - e. Heat, mass, and momentum transfer,
  - f. Chemical reaction engineering,
  - g. Continuous and staged separation operations,
  - h. Process dynamics and control,
  - i. Modern experimental and computing techniques, and
  - j. Process design.

# **PROGRAM ASSESSMENT DATA AY2022**

UNITED STATES MILITARY ACADEMY  
DEPARTMENT OF CHEMISTRY AND LIFE SCIENCE  
CHEMICAL ENGINEERING PROGRAM  
April 17, 2023

<u>Student Outcome</u>	<u>Page</u>
1.....	<a href="#"><u>1</u></a>
2.....	<a href="#"><u>3</u></a>
3.....	<a href="#"><u>5</u></a>
4.....	<a href="#"><u>7</u></a>
5.....	<a href="#"><u>9</u></a>
6.....	<a href="#"><u>12</u></a>
7.....	<a href="#"><u>14</u></a>
8.....	<a href="#"><u>19</u></a>

## Evaluations

Faculty.....	<a href="#"><u>21</u></a>
Advisory Board.....	<a href="#"><u>22</u></a>
Program Director .....	<a href="#"><u>23</u></a>

Note: When complete, the results of the surveys are summarized in the “Evaluations” section. The evaluation section is a working draft as of 20 July 2022. Faculty data will be added when complete. Advisory board assessment is not available until spring 2023 after the advisory board meeting.





### Level of Achievement of Student Outcome 1:

On completion of the chemical engineering program, our graduates will be able to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. Fundamentals of Engineering Examination, once/yr.
3. End-of-Semester Student Surveys, once/semester.
4. Chemical Engineering Program Exit Survey, once/yr.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

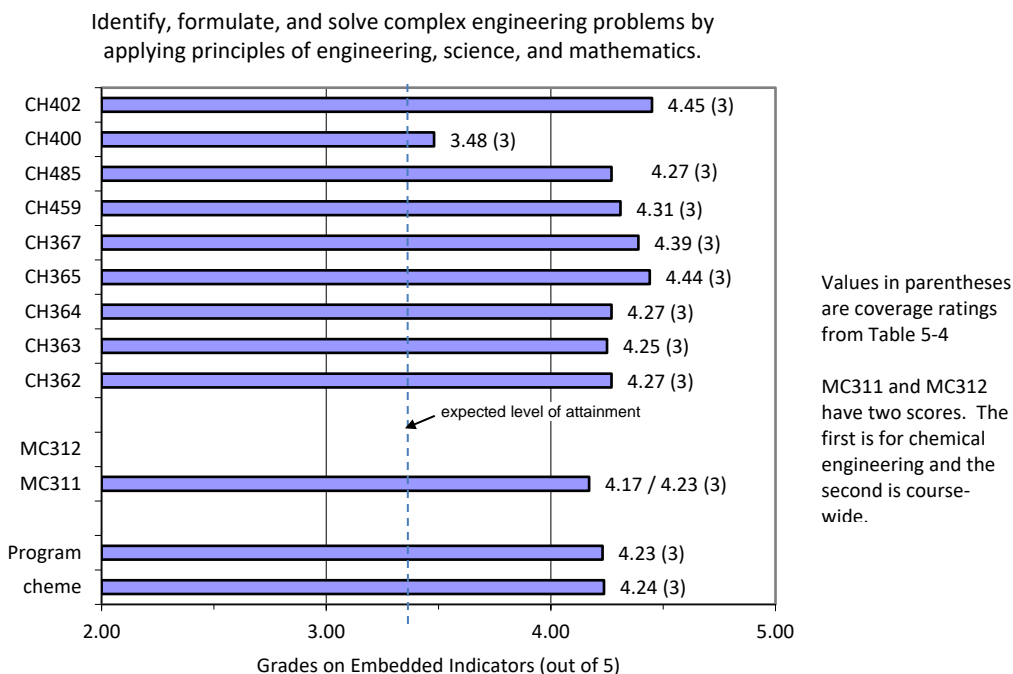


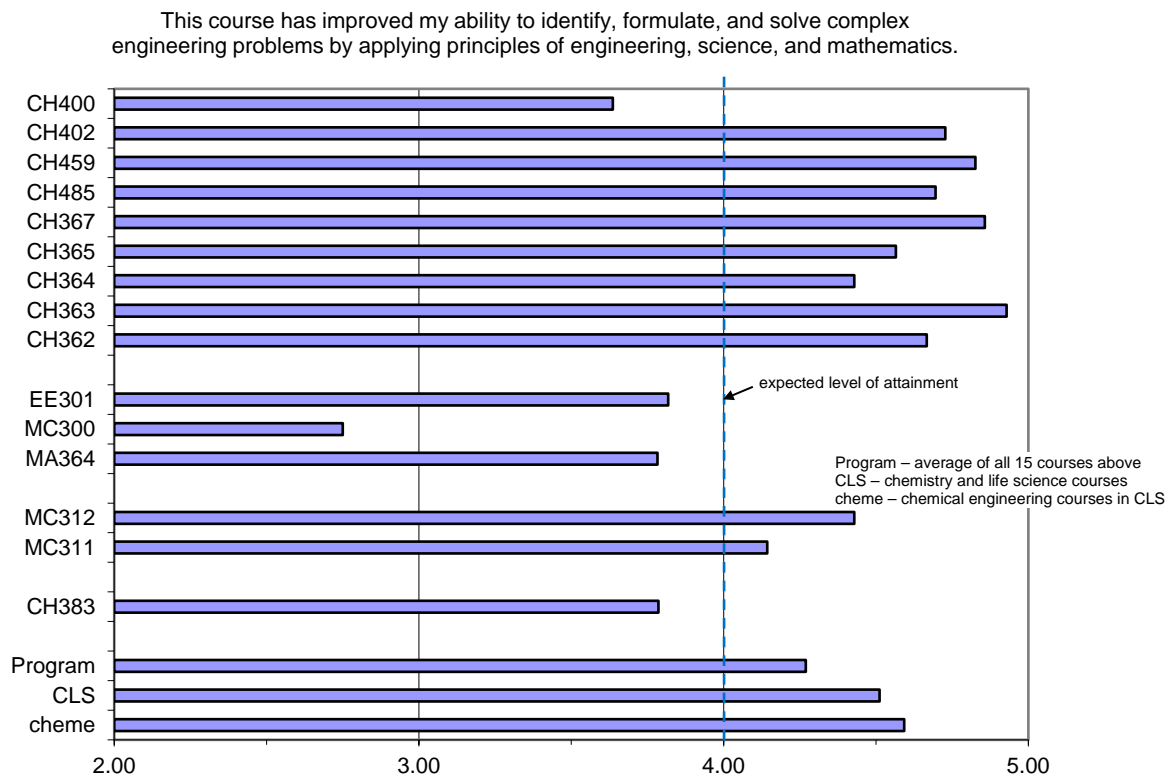
Figure 1-1. Coursework Embedded Indicator results for Student Outcome 1.

2. Fundamentals of Engineering Examination (FEE). According to the 2022 report from NCEES, 21 out of 23, or 91.3% of the students in the Class of 2022 took and passed the FE Exam. The national average passing in 2022 was 70.7%, and this is our expected level of attainment. In the previous five years, the pass rates were 85.0% in 2021, 77.8% in 2020, 100% in 2019, 85.7% in 2018, and 93.8% in 2017. Our running average over those five years is  $88.4\% \pm 8.6\%$  ( $76.0\% \pm 2.0\%$  for the national average).

Note: We are **above** the national average for the pass rate for the past six years, and the national average is our expected level of attainment.

### 3. End of Semester Student Surveys

Figure 1-2. End-of-Semester Student Survey responses for Student Outcome 1.



4. Chemical Engineering Program Exit Survey. This survey is issued to firsties at the end of their last semester. In this question, they were asked whether they agree with the statement “The program has prepared me to Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.” 22 out of 23 cadets completed the survey (one cadet was on medical leave). All 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 17/22 replying that they strongly agreed (score = 5/5) and 7/20 that they agreed (score = 4/5). This equates to a mean score of  $4.77/5.00 \pm 0.43$  for the 22 cadets participating in the survey. The expected level of attainment on this survey is 4.00/5.00.

### Level of Achievement of Student Outcome 2:

On completion of the chemical engineering program, our graduates will be able to 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.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. End of Semester Student Surveys, once/semester.
3. Course Grades in CH402 Chemical Engineering Process Design, once/yr.
4. Chemical Engineering Program Exit Survey, once/yr.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

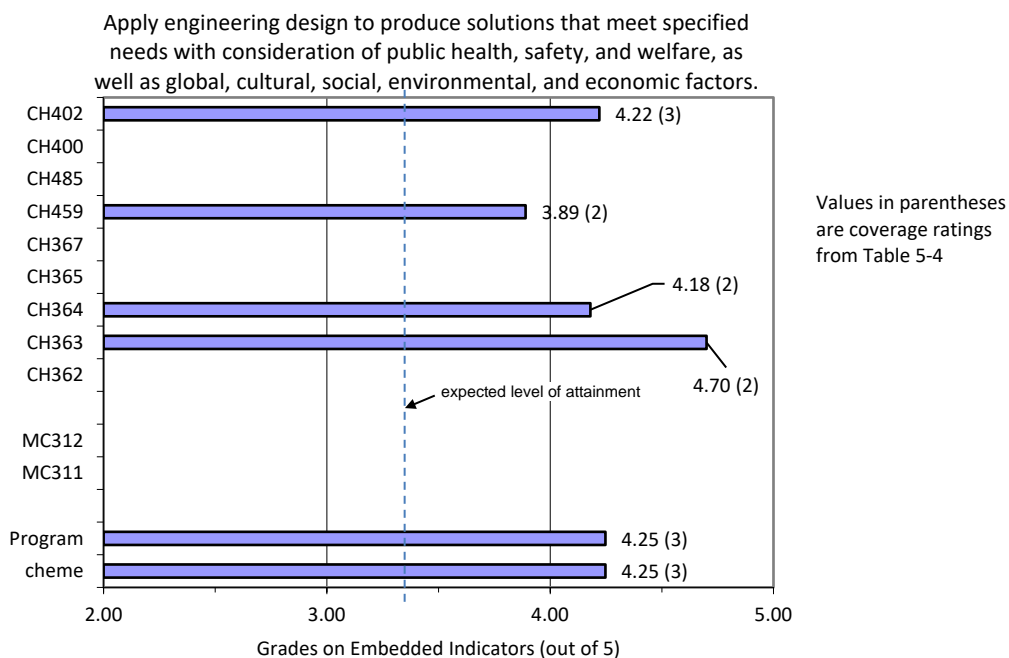


Figure 2-1. Coursework Embedded Indicator results for Student Outcome 2.

## 2. End of Semester Student Surveys

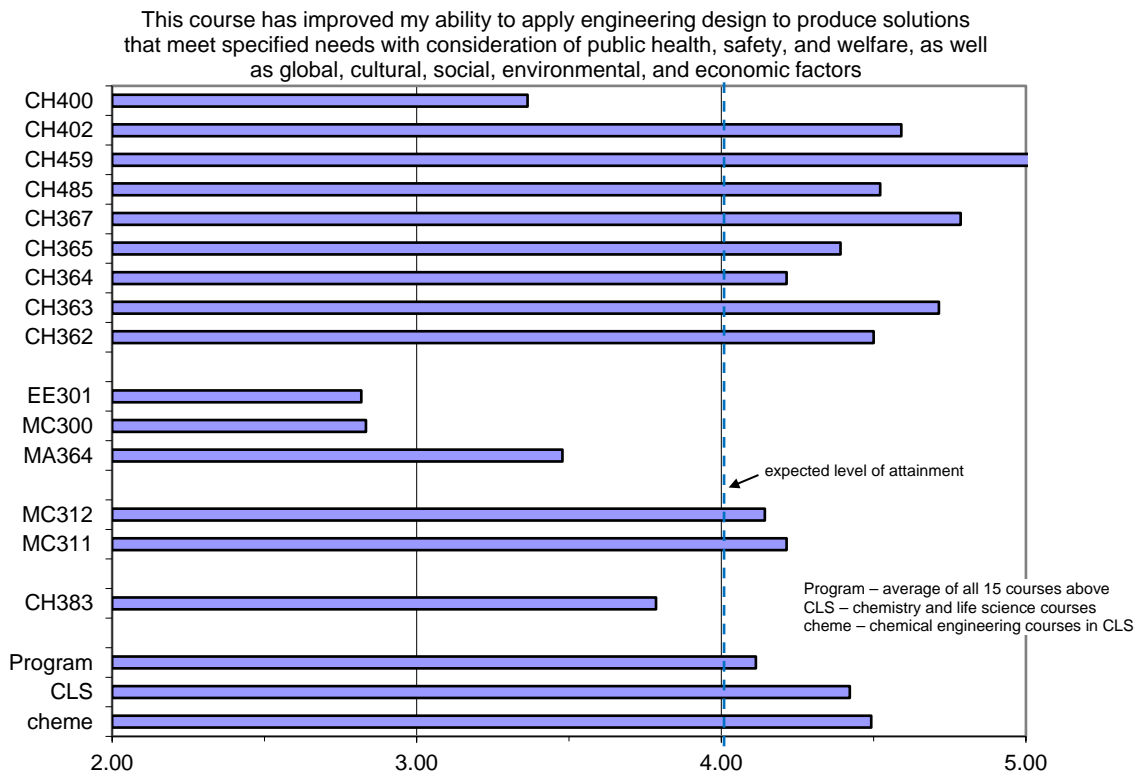


Figure 2-2. End-of-Semester Student Survey responses for Student Outcome 2.

3. The average course grade in CH402 Chemical Engineering Process Design was  $3.33 \pm 0.50$  ( $n=23$ ) in AY22, compared to  $3.46 \pm 0.68$  ( $n=20$ ) in AY21,  $3.26 \pm 0.70$  ( $n=29$ ) in AY20,  $3.27 \pm 0.92$  ( $n=21$ ) in AY19,  $3.37 \pm 0.66$  ( $n=19$ ) in AY18, and  $2.73 \pm 0.39$  ( $n=16$ ) in AY17. *The 5-year running average for the previous five years is 3.22, and this is our expected level of attainment. This year's score was above the 5-year running average.*
4. Chemical Engineering Program Exit Survey. As stated earlier, this survey is given to firsties at the end of their last semester. In this question, they were asked whether or not they agree with the statement "The program has prepared me to 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." 22 out of 23 cadets completed the survey (one cadet was on medical leave). Of these, 21 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 12/22 replying that they strongly agreed (score = 5/5), 9/22 replying that they agreed (score = 4/5), and 1/20 that they were neutral (score = 3/5). This equates to a mean score of  $4.50/5.00 \pm 0.60$  for the 22 cadets. The expected level of attainment on this survey is 4.00/5.00.

### Level of Achievement of Student Outcome 3:

On completion of the chemical engineering program, our graduates will be able to communicate effectively with a range of audiences.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. End of Semester Student Surveys, once/semester.
3. Course Grades in CH459 Unit Operations Laboratory, once/yr.
4. Chemical Engineering Program Exit Survey, once/yr.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

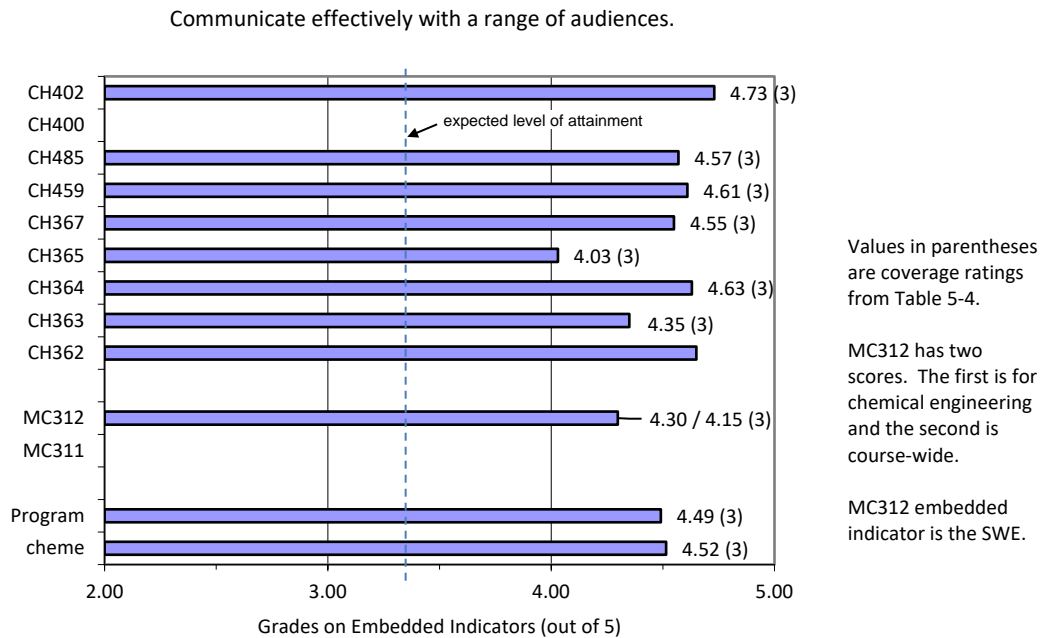


Figure 3-1. Coursework Embedded Indicator results for Student Outcome 3.

## 2. End of Semester Student Surveys

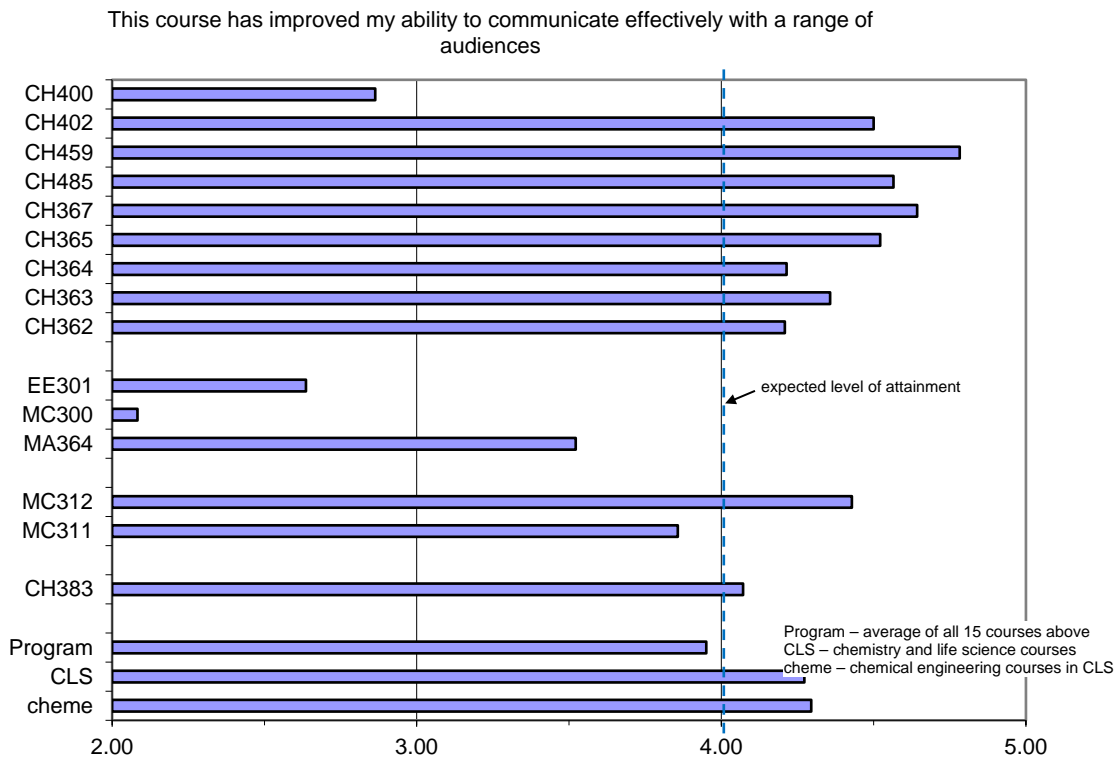


Figure 3-2. End-of-Semester Student Survey responses for Student Outcome 3.

3. The average course grade in CH459 Chemical Engineering Laboratory was  $3.80 \pm 0.42$  ( $n=23$ ) in AY22, compared to  $3.67 \pm 0.75$  ( $n=20$ ) in AY21,  $3.53 \pm 0.48$  ( $n=29$ ) in AY20,  $3.52 \pm 0.44$  ( $n=21$ ) in AY19,  $3.42 \pm 0.64$  ( $n=19$ ) in AY18, ND  $3.54 \pm 0.30$  ( $n=16$ ) in AY17. *The 5-year running average is 3.54, and this is our expected level of attainment. This year's score was **above** the 5-year running average, which is a significant improvement.*
4. Chemical Engineering Program Exit Survey. As stated earlier, this survey is given to firsties at the end of their last semester. In this question, they were asked whether they agree with the statement "The program has prepared me to communicate effectively with a range of audiences." 22 out of 23 cadets completed the survey (one cadet was on medical leave). Of these, 22 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 15/22 replying that they strongly agreed (score = 5/5), and 7/20 replying that they agreed (score = 4/5). This equates to a mean score of  $4.68/5.00 \pm 0.48$  for the 22 cadets. The expected level of attainment on this survey is 4.00/5.00.

#### Level of Achievement of Student Outcome 4:

On completion of the chemical engineering program, our graduates will be able to 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.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. Fundamentals of Engineering Examination Performance Index, once/yr.
3. End of Semester Student Surveys, once/semester.
4. Chemical Engineering Program Exit Survey, once/yr.
5. Completion of Cadet Character Education Program, once/yr.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

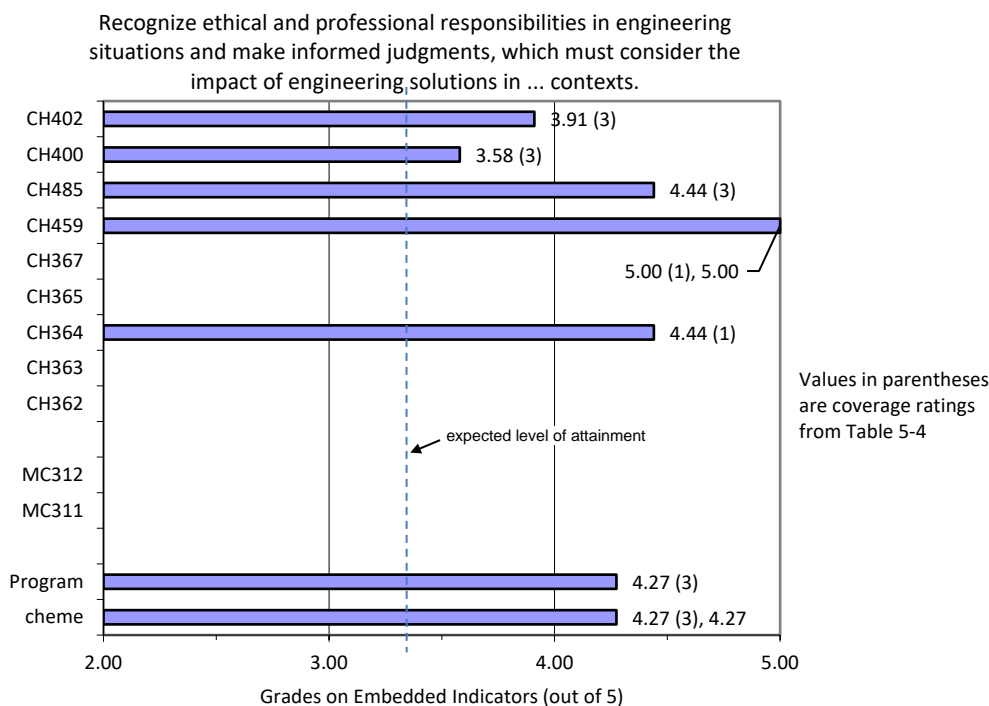


Figure 4-1. Coursework Embedded Indicator results for Student Outcome 4.

2. Fundamentals of Engineering Examination Performance, Self-Study Table 4-2.

Subject	Outcome	Questions	USMA	National (expected level of attainment)
Ethics and Professional Practice	4	3	13.7	12.0 ± 4.3
Economics	4	4	11.9	10.1 ± 3.4

Note: the national average is our expected level of attainment, and we are within the standard deviation reported by NCEES.



### 3. End of Semester Student Surveys

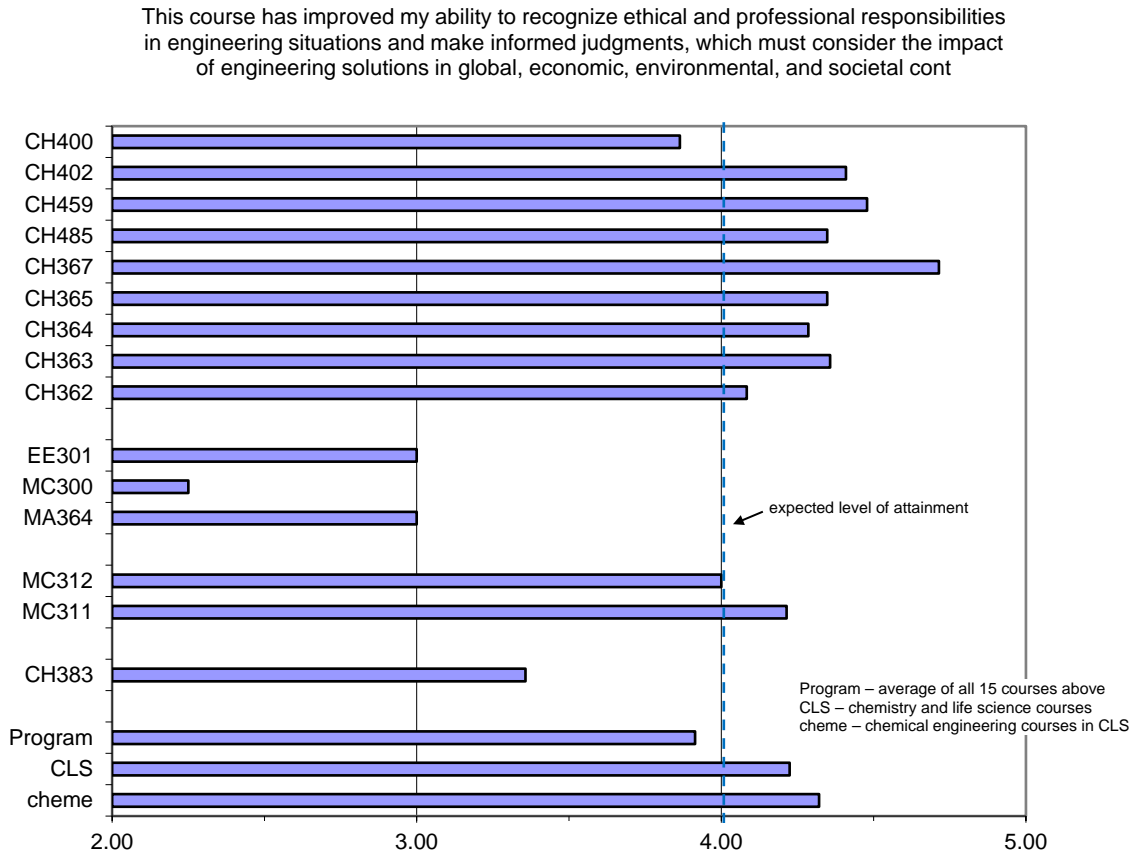


Figure 4-2. End-of-Semester Student Survey responses for Student Outcome 4.

4. Chemical Engineering Program Exit Survey. This survey is given to the firsties at the end of their last semester. In this question, they were asked whether or not they agree with the statement “The program has prepared me to 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.” 22 out of 23 cadets completed the survey (one was on medical leave). Of these, 19 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 10/22 replying that they strongly agreed (score = 5/5), 9/22 replying that they agreed (score = 4/5), and 3/20 replying that they were neutral (score = 3/5). This equates to a mean score of  $4.32/5.00 \pm 0.72$  for the 22 cadets. The expected level of attainment is 4.00/5.00.
5. Training in honor and ethics takes place in the Cadet Character Education Program (CCEP) during the academic year and summer terms. The program is overseen by the Commandant of Cadets through the Simon Center for the Professional Military Ethic. CCEP customizes instruction to each of the four year-groups of cadets, who interact with faculty volunteers who share their perspectives and experience in the Armed Forces, with industry, and at other civilian institutions. All 23 chemical engineering cadets successfully completed the 4-year CCEP program.

### Level of Achievement of Student Outcome 5:

On completion of the chemical engineering program, our graduates will be able to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. End of Semester Student Surveys, once/semester.
3. Chemical Engineering Program Exit Survey, once/yr.
4. Multidisciplinary Skills Rubric, once/yr.

#### *Assessment Results:*

##### 1. Chemical & Mechanical Engineering Coursework Embedded Indicators

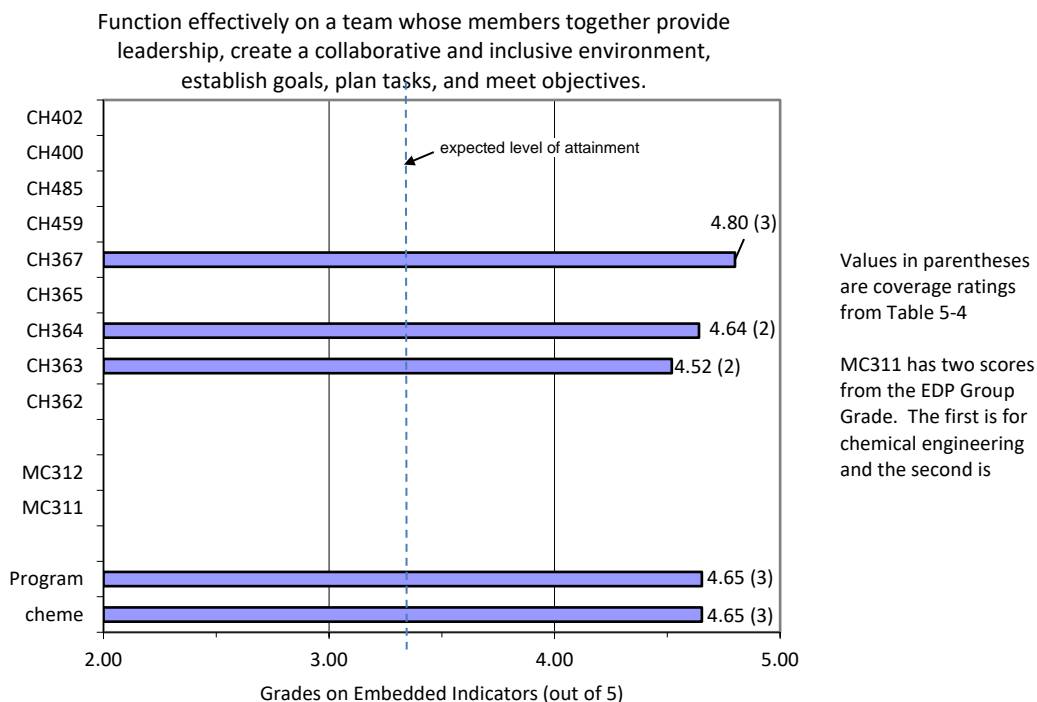


Figure 5-1. Coursework Embedded Indicator results for Student Outcome 5.

## 2. End of Semester Student Surveys

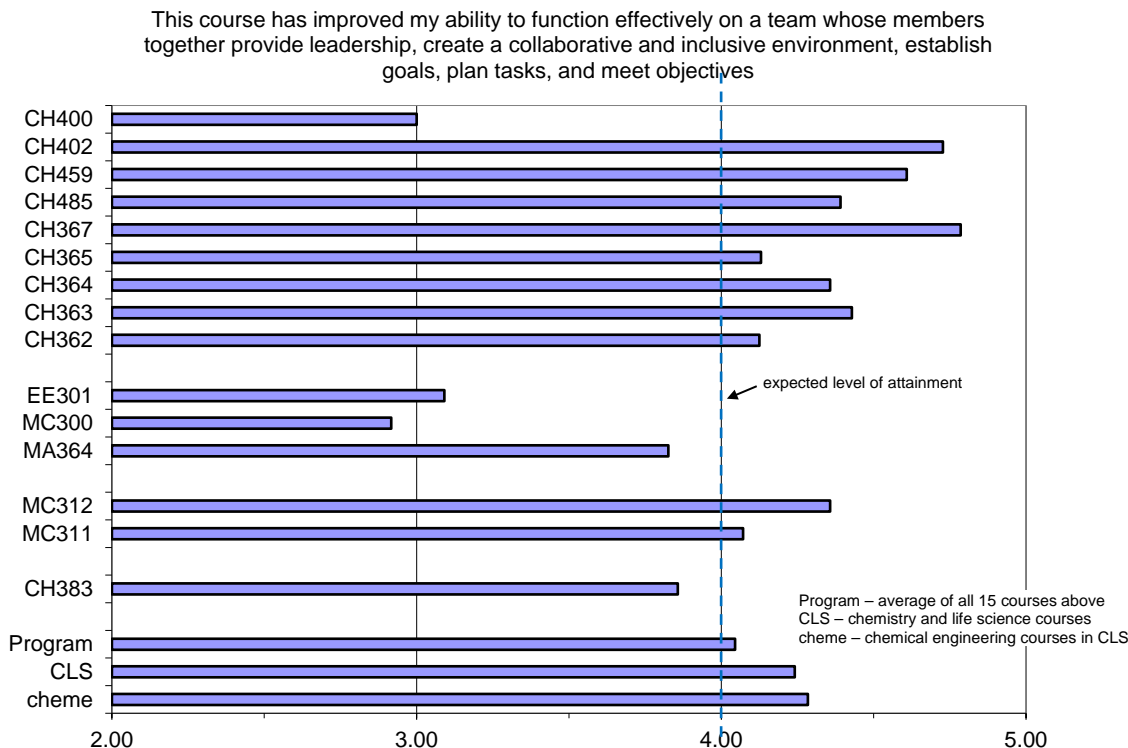


Figure 5-2. End-of-Semester Student Survey responses for Student Outcome 5.

3. Chemical Engineering Program Exit Survey. As stated earlier, this survey is given to the firsties at the end of their last semester. In this question, they were asked whether or not they agree with the statement “The program has prepared me to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.” 22 out of 23 cadets completed the survey (one cadet was on medical leave). Of these, 22 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 16/20 replying that they strongly agreed (score = 5/5), and 6/22 replying that they agreed (score = 4/5). This equates to a mean score of  $4.73/5.00 \pm 0.46$  for the 22 cadets. The expected level of attainment on this survey is 4.00/5.00.
4. Teamwork Skills Rubric. The rubric is used to assess performance in four skills associated with the ability to function on effectively on a team, namely technical competence, communication, organization, and teamwork. The rubrics are completed by the cadets after each laboratory exercise in CH459. The results were averaged over each round-robin and reported below using the actual rubric for formatting. The superscript “a” next to the averages are for team assessment of the group leader (TAL) and “b” designates group leader assessment of the team (GLAT). The expected level of attainment is 4.0. The color shading indicates the

relationship of the averages to the expected level of attainment. Red shading indicates when improvement is needed.

Your Name: Dr. Enoch Nagelli				Person Assessed: Cadets in CH459					
Your Position: CH459 CD				Major of Person Assessed: Chemical Engineering					
	1 – Needs Improvement	1	2	3 – Meets Expectations	3	4	5 – Exceeds Expectations	5	N/A
Technical Competence	Some misunderstandings of the technical content.			Demonstrated knowledge of the technical content.			Exceptional knowledge of technical content.	5.0 <sup>a</sup> ±.0 <sup>c</sup> 4.9 <sup>b</sup> ±.08 <sup>c</sup>	
Communication	Lacked sensitivity and/or did not provide specific suggestions for improvement.			Effectively communicated important points.			Exceptional ability to explain important points. Very effectively communicated ideas for improvement.	4.9 <sup>a</sup> ±.03 <sup>c</sup> 4.9 <sup>b</sup> ±.02 <sup>c</sup>	
Organization	Was not prepared or did not give sufficient time to prepare.			Demonstrated effective organization during class.			Was exceptionally efficient, timely and responsive throughout the entire process.	4.9 <sup>a</sup> ±.03 <sup>c</sup> 5.0 <sup>b</sup> ±.0 <sup>c</sup>	
Teamwork	Demonstrated limited ability to see other perspectives or find common ground.			Worked collaboratively with team members to reach consensus.			Exceptional ability to help group find common ground or resolve conflict in order to ultimately reach consensus.	4.9 <sup>a</sup> ±.02 <sup>c</sup> 5.0 <sup>b</sup> ±0.0 <sup>c</sup>	
Are the cadets capable of functioning on multidisciplinary teams? Yes	Comments: Each cadet was group leader twice. Footnote “a” designates the average of all Team Assessments of Leader (TAL) scores, while “b” designates average of all Group Leader Assessment (GLAT) scores. Footnote “c” designates standard deviations.						Assignment used for assessment: AY22, Round Robin 1		

Your Name: Dr. Enoch Nagelli				Person Assessed: Cadets in CH459					
Your Position: CH459 CD				Major of Person Assessed: Chemical Engineering					
	1 – Needs Improvement	1	2	3 – Meets Expectations	3	4	5 – Exceeds Expectations	5	N/A
Technical Competence	Some misunderstandings of the technical content.			Demonstrated knowledge of the technical content.			Exceptional knowledge of technical content.	4.9 <sup>a</sup> ±.02 <sup>c</sup> 5.0 <sup>b</sup> ±0.0 <sup>c</sup>	
Communication	Lacked sensitivity and/or did not provide specific suggestions for improvement.			Effectively communicated important points.			Exceptional ability to explain important points. Very effectively communicated ideas for improvement.	4.9 <sup>a</sup> ±.05 <sup>c</sup> 5.0 <sup>b</sup> ±0.0 <sup>c</sup>	
Organization	Was not prepared or did not give sufficient time to prepare.			Demonstrated effective organization during class.			Was exceptionally efficient, timely and responsive throughout the entire process.	4.9 <sup>a</sup> ±.02 <sup>c</sup> 5.0 <sup>b</sup> ±0.0 <sup>c</sup>	
Teamwork	Demonstrated limited ability to see other perspectives or find common ground.			Worked collaboratively with team members to reach consensus.			Exceptional ability to help group find common ground or resolve conflict in order to ultimately reach consensus.	4.9 <sup>a</sup> ±.05 <sup>c</sup> 5.0 <sup>b</sup> ±0.0 <sup>c</sup>	
Are the cadets capable of functioning on multidisciplinary teams? Yes	Comments: Each cadet was group leader twice. Footnote “a” designates the average of all Team Assessments of Leader (TAL) scores, while “b” designates average of all Group Leader Assessment (GLAT) scores. Footnote “c” designates standard deviations.						Assignment used for assessment: AY22, Round Robin 2		

### Level of Achievement of Student Outcome 6:

On completion of the chemical engineering program, our graduates will be able to develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. End-of-Semester Student Surveys, once/semester.
3. Chemical Engineering Program Exit Survey, once/yr.
4. Course Grades in CH459 Unit Operations Laboratory, once/yr.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

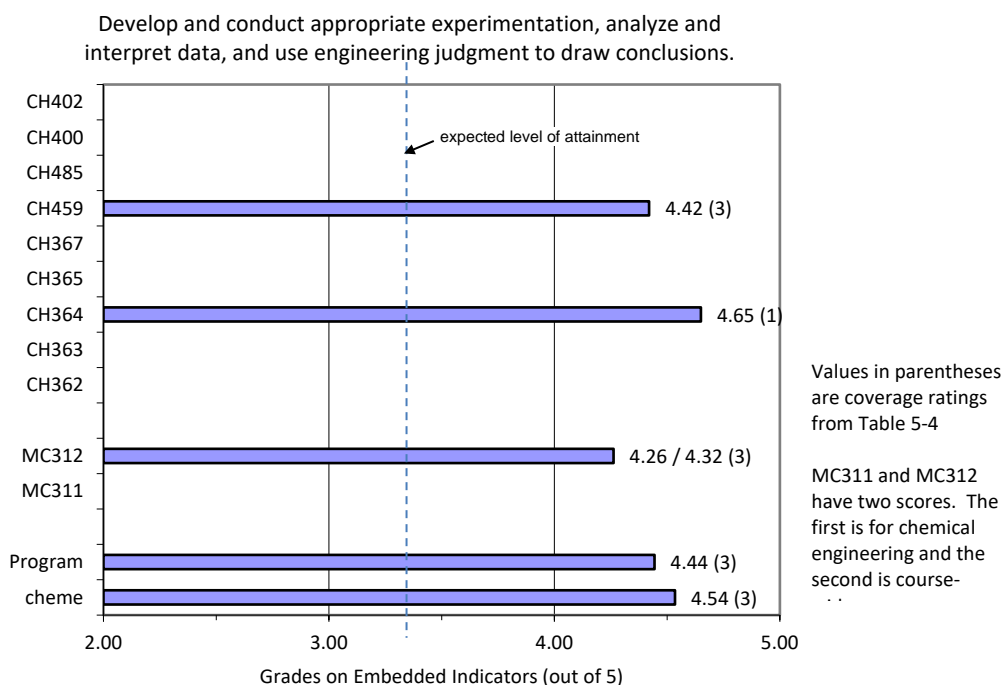


Figure 6-1. Coursework Embedded Indicator results for Student Outcome 6.

## 2. End of Semester Student Surveys

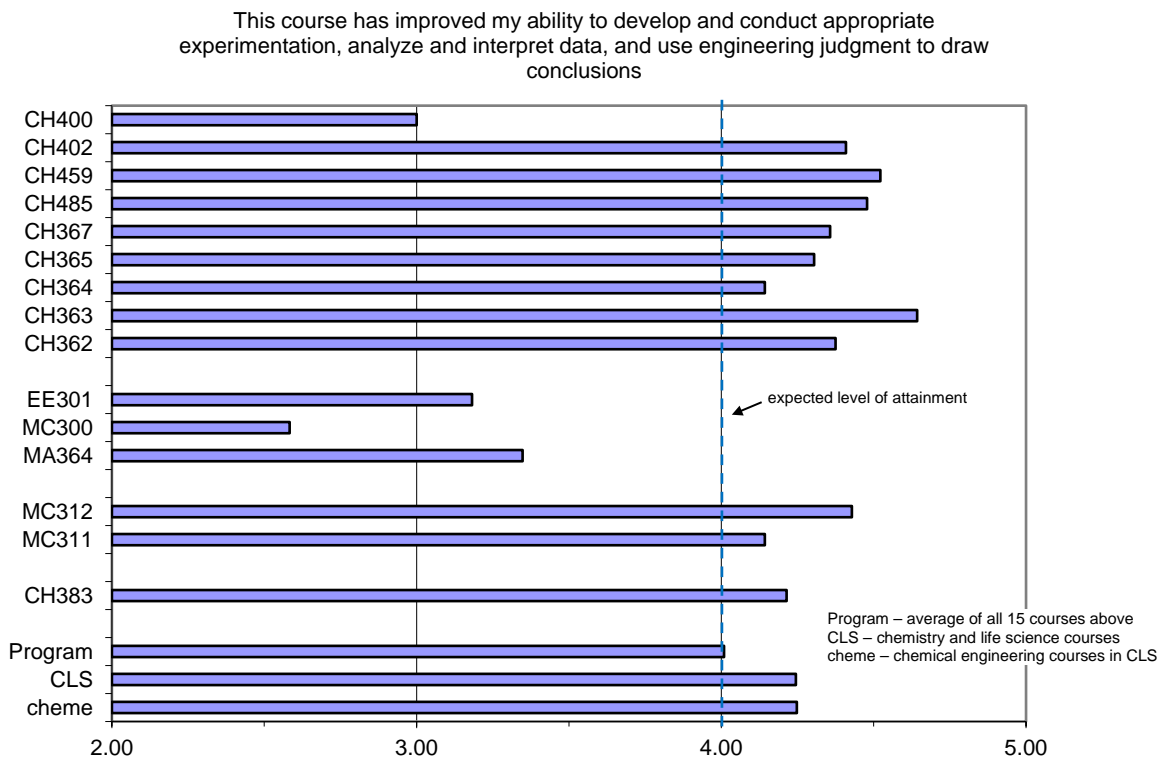


Figure 6-2. End-of-Semester Student Survey responses for Student Outcome 6.

3. Chemical Engineering Program Exit Survey. As stated earlier, this survey is given to the firsties at the end of their last semester. In this question, they were asked whether they agree with the statement “The program has prepared me to Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.” 22 out of 23 cadets completed the survey (one cadet was on medical leave). Of these, 20 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 14/22 replying that they strongly agreed (score = 5/5), 6/22 replying that they agreed (score = 4/5), 1/22 replying that they were neutral (score = 3/5), and 1/22 that they disagreed (score = 2/5). This equates to a mean score of  $4.50/5.00 \pm 0.80$  for the 22 cadets. The expected level of attainment on this survey is 4.00/5.00.
4. The average course grade in CH459 Chemical Engineering Laboratory was  $3.80 \pm 0.42$  (n=23) in AY22, compared to  $3.67 \pm 0.75$  (n=20) in AY21,  $3.53 \pm 0.48$  (n=29) in AY20,  $3.52 \pm 0.44$  (n=21) in AY19,  $3.42 \pm 0.64$  (n=19) in AY18, ND  $3.54 \pm 0.30$  (n=16) in AY17. The 5-year running average is 3.54, and this is our expected level of attainment. This year’s score was **above** the 5-year running average, which is a significant improvement.

### Level of Achievement of Student Outcome 7:

On completion of the chemical engineering program, our graduates will be able to acquire and apply new knowledge as needed, using appropriate learning strategies.

#### *Assessment Instruments and Frequency:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators, once/yr.
2. Percent of eligible students taking the Fundamentals of Engineering Examination (FEE), once/yr.
3. End of Semester Student Surveys, once/semester.
4. Chemical Engineering Program Exit Survey, once/yr.
5. Lifelong Learning Skills Rubric, twice per year.
6. Contemporary Issues Rubric, multiple times per year.

#### *Assessment Results:*

1. Chemical & Mechanical Engineering Coursework Embedded Indicators

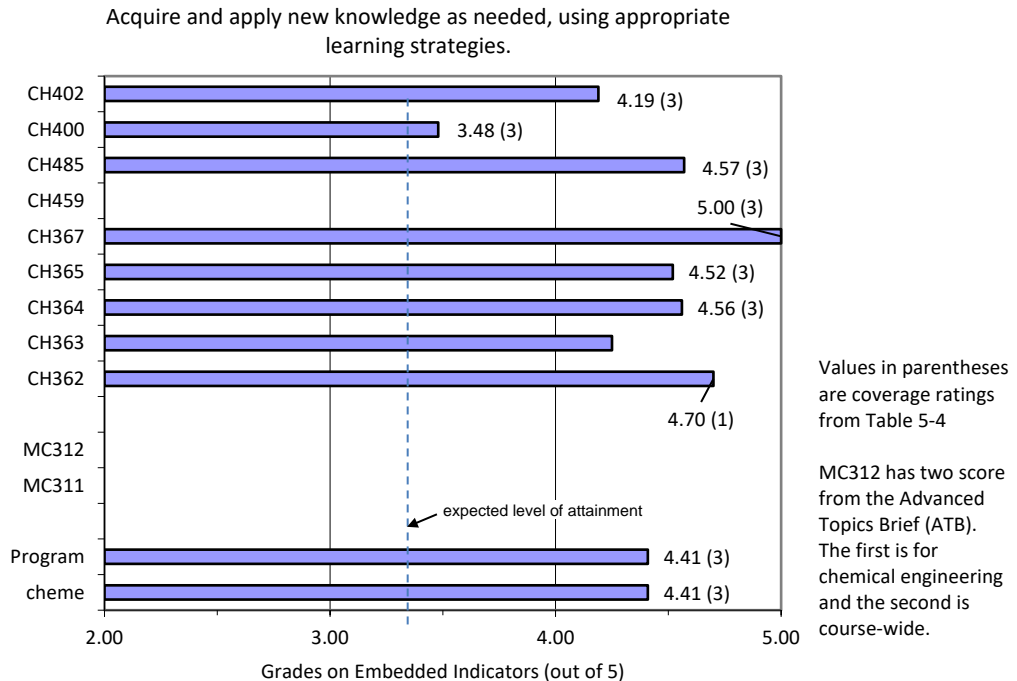


Figure 7-1. Coursework Embedded Indicator results for Student Outcome 7.

2. Percent of Eligible Cadets taking the Fundamentals of Engineering Examination (FEE). For the Class of 2022, 23 of 23 chemical engineering cadets (100% of eligible cadets) prepared for and took the FEE. This compares to 100% from years 2016 to 2019, with 31% in 2020 (9 of 29), and 100% in 2021 and 2022. The decline in participation in 2020 was due to closure of NCEES test centers nationwide in addition to restrictions on cadet movement during the COVID-19 crisis. NCEES reported a decline from 1047 participants in 2019 to 480 in 2020, which recovered somewhat to 668 in 2021 and 600 in 2022. We also recognize that three of the four first-time takers that failed the exam on their first attempt decided to re-take the exam at their own expense. **Note: The participation rate is EXCELLENT.**

### 3. End of Semester Student Surveys

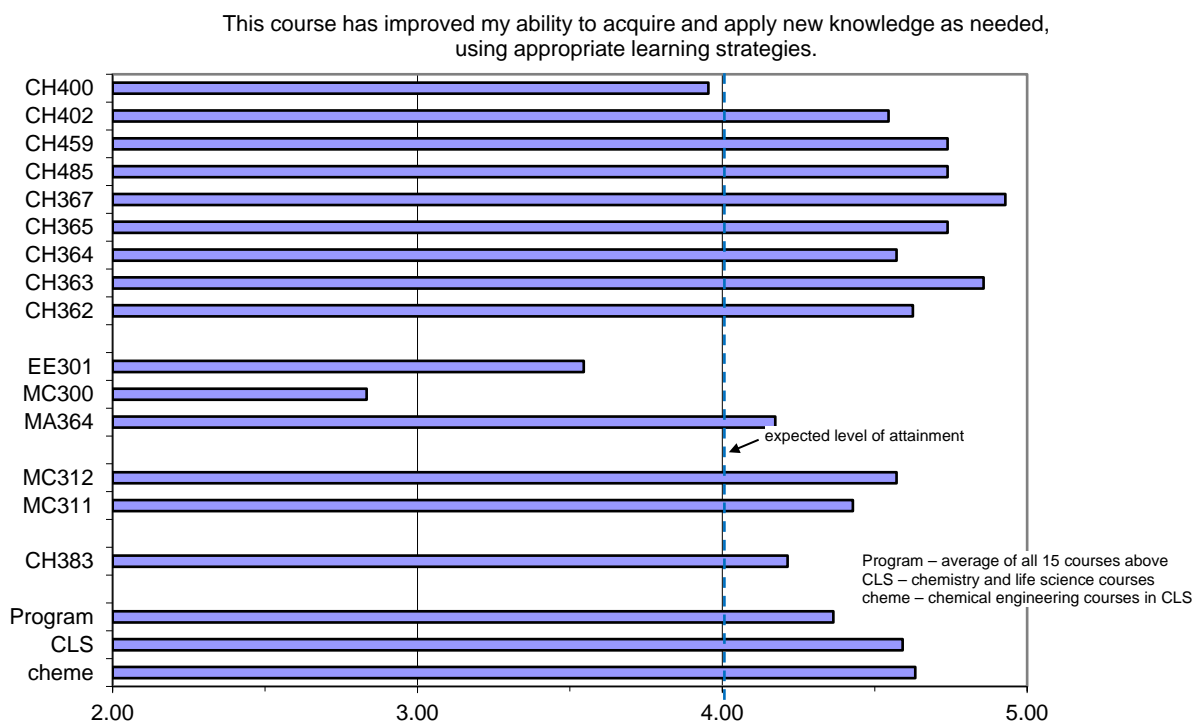


Figure 7-2. End-of-Semester Student Survey responses for Student Outcome 7.

4. Chemical Engineering Program Exit Survey. As stated earlier, this survey is given to the firsties at the end of their last semester. In this question, they were asked whether they agree with the statement “The program has prepared me to Acquire and apply new knowledge as needed, using appropriate learning strategies.” Of these, 21 out of 22 cadets said that they either agreed or strongly agreed (score = 5/5 or 4/5), with 20/22 replying that they strongly agreed (score = 5/5), 1/20 replying that they agreed (score = 4/5), and 1/22 replying that they were neutral (score = 3/5). This equates to a mean score of  $4.86/5.00 \pm 0.47$  for the 22 cadets. The expected level of attainment on this survey is 4.00/5.00.
5. Lifelong Learning Skills Rubric. This rubric, when used in tandem with the resume writing assignment in CH365, is designed to assess performance in four skills associated with the ability to acquire new knowledge, namely: rubric row 1 - engagement (in professional activities), rubric row 2 - recognition (of skills learned in the program), rubric row 3 – intellectual growth (recognition of new skills), and rubric row 4 – communication (in resume format). Resumes were written at the beginning of the semester (assignment 1.1), then revised at the end of the semester (assignment 2.0). One rubric is shown for each assignment below, along with cadet averages and standard deviations. The expected levels of attainment are color-coded, with red indicating a need for improvement, yellow indicating acceptable



performance, and green indicating that expectations are met or exceeded. Instructor comments are in the rubrics.

Instructor's Name: <b>Biaglow</b>				Cadet Assessed:			
Your Position: <b>Instructor, CH365</b> (e.g., CD CH365)				Cadet Major: <b>Chemical Engineering</b> (e.g., Chem. Eng.)			
	<b>1 – Needs Improvement</b>	<b>1</b>	<b>2</b>	<b>3 – Meets Expectations</b>	<b>3</b>	<b>4</b>	<b>5 – Exceeds Expectations</b>
<b>Engagement Outcome 7</b>	No evidence of pre-professional activities.			References to pre-professional activities are lacking or connections to chemical engineering are weak or implied.			Uses examples of pre-professional chemical engineering activities.
<b>Recognition Outcome 7</b>	Skills learned in chemical engineering courses taken in previous semesters are not listed.			Skills are listed, but the skills are vaguely described, or connection to chemical engineering concepts is not clear.			Identifies specific skills learned in chemical engineering courses.
<b>Intellectual Growth Outcome 7</b>	Unable to identify new concepts learned this semester.			Changes are apparent in document, but connections to recent activities in chemical engineering are weak or implied.			Addition of multiple skills acquired this semester.
<b>Communication Outcome 3</b>	Resume lacks organization or cohesion. Numerous grammatical errors that may interfere with meaning. Target audience unclear.			Occasional grammar errors that do not impede meaning. Demonstrates ability to write a basic resume, but document is uninteresting and flat.			Demonstrates an ability to effectively communicate in the resume format. Clear, concise content. Resume is interesting.
Has this cadet demonstrated SO7 (acquiring knowledge)? (Y/N) Y	Comments: Cadet scores were good overall but some grades were held down because some cadets did not read the assignment carefully and ignored the guidance and wrote about ideas that did not meet rubric requirements. Final Grade: <b>4.2 ± 1.1 / 5.0</b>					Assignment used for assessment: (e.g., resume draft 1.1 in CH365) <b>resume draft 1.1 in CH365</b>	

Instructor's Name: <b>Biaglow</b>				Cadet Assessed:			
Your Position: <b>Instructor, CH365</b> (e.g., CD CH365)				Cadet Major: <b>Chemical Engineering</b> (e.g., Chem. Eng.)			
	<b>1 – Needs Improvement</b>	<b>1</b>	<b>2</b>	<b>3 – Meets Expectations</b>	<b>3</b>	<b>4</b>	<b>5 – Exceeds Expectations</b>
<b>Engagement Outcome 7</b>	No evidence of pre-professional activities.			References to pre-professional activities are lacking or connections to chemical engineering are weak or implied.			Uses examples of pre-professional chemical engineering activities.
<b>Recognition Outcome 7</b>	Skills learned in chemical engineering courses taken in previous semesters are not listed.			Skills are listed, but the skills are vaguely described, or connection to chemical engineering concepts is not clear.			Identifies specific skills learned in chemical engineering courses.
<b>Intellectual Growth Outcome 7</b>	Unable to identify new concepts learned this semester.			Changes are apparent in document, but connections to recent activities in chemical engineering are weak or implied.			Addition of multiple skills acquired this semester.
<b>Communication Outcome 3</b>	Resume lacks organization or cohesion. Numerous grammatical errors that may interfere with meaning. Target audience unclear.			Occasional grammar errors that do not impede meaning. Demonstrates ability to write a basic resume, but document is uninteresting and flat.			Demonstrates an ability to effectively communicate in the resume format. Clear, concise content. Resume is interesting.
Has this cadet demonstrated SO7 (acquiring knowledge)? (Y/N) Y	Comments: Scores increased in intellectual growth as instructor was able to provide mentoring on introspection by cadets regarding previous experiences in chemical engineering courses. Final Grade: <b>4.5 ± 0.9 / 5.0</b>					Assignment used for assessment: (e.g., resume draft 1.1 in CH365) <b>resume draft 2.0 in CH365</b>	

There is normally improvement in scores in draft 2.0 as cadets incorporate instructor comments to improve and polish their documents. Version 2.0, though, requires articulation of new skills acquired during the semester. Scores can go down if cadets do not show new activities and skills learned during the semester, and in some individual cases the scores did drop. This explains why the intellectual growth row did not increase as much as one might expect. However, overall and on average, the program scores are solidly in the green in all four categories by the end of the semester.

## 6. Contemporary Issues Rubric.

Instructor's Name: <b>LTC Cowart</b>				Cadet Assessed: <b>All Cadets in CH485</b>				
Your Position: <b>CD, CH485</b> (e.g., CD CH485)				Cadet Major: <b>Chemical Engineering</b> (e.g., Chem. Eng.)				
	<b>1 – Needs Improvement</b>	<b>1</b>	<b>2</b>	<b>3 – Meets Expectations</b>	<b>3</b>	<b>4</b>	<b>5 – Exceeds Expectations</b>	<b>5</b>
<b>Acquiring Knowledge</b> <b>Outcome 7</b>	Cites references but they are not substantive or do not address assignment. Context is weak or implied. Uses generic arguments or lacks specificity.			Cites at least two references relevant to the assignment. References have been adequately studied and reworded to support a thesis.		<b>3.9</b> +/- <b>1.0</b>	Uses multiple substantive examples or scholarly articles in an integrative fashion to support a thesis.	
<b>Technical Competence</b> <b>Outcomes 8</b>	Demonstrates poor or incomplete understanding of technical content.			Demonstrates some knowledge of the technical content, but explanation lacks adequate depth.	<b>3.4</b> +/- <b>0.7</b>		Demonstrates exceptional knowledge of technical content.	
<b>Synthesis of Ideas</b> <b>Outcome 3</b>	Does not have a premise or does not connect issues in essay to concepts in chemical engineering.			Makes connections to chemical engineering concepts, but the connections are weak or implied or premise is weak.		<b>3.7</b> +/- <b>0.6</b>	Makes very clear connections between premise and chemical engineering concepts.	
<b>Grammar and Structure</b> <b>Outcome 3</b>	Lacks organization or cohesion. Numerous grammatical errors or errors interfere with meaning. Thesis lacking or implied.			Occasional grammar that do not impede meaning. Demonstrates ability to write an essay but lacks cohesion or completeness. Thesis not fully supported.		<b>3.7</b> +/- <b>1.0</b>	Demonstrates an ability to effectively communicate in the essay format. Fully supported, clear, concise thesis. Writing style was exceptionally clear and articulate.	
Has this cadet demonstrated SO7 (acquiring knowledge)? (Y/N) <b>Y</b>	Comments: <b>Cadets met expectations on the draft writing assignment. Cadets demonstrated acquisition of new knowledge and generally wrote in an acceptable format. Technical content with respect to heat &amp; mass transfer can be improved, as well as writing organization.</b>					Assignment used for assessment: (e.g., draft 1 writing assignment 1 in CH485) <b>CH485 Writing DRAFT</b>		
	Final Grade: <b>3.7 ± 0.8</b>							

Instructor's Name: <b>LTC Cowart</b>				Cadet Assessed: <b>All Cadets in CH485</b>				
Your Position: <b>CD, CH485</b> (e.g., CD CH485)				Cadet Major: <b>Chemical Engineering</b> (e.g., Chem. Eng.)				
	<b>1 – Needs Improvement</b>	<b>1</b>	<b>2</b>	<b>3 – Meets Expectations</b>	<b>3</b>	<b>4</b>	<b>5 – Exceeds Expectations</b>	<b>5</b>
<b>Acquiring Knowledge</b> <b>Outcome 7</b>	Cites references but they are not substantive or do not address assignment. Context is weak or implied. Uses generic arguments or lacks specificity.			Cites at least two references relevant to the assignment. References have been adequately studied and reworded to support a thesis.			Uses multiple substantive examples or scholarly articles in an integrative fashion to support a thesis.	<b>4.8 +/- 0.4</b>
<b>Technical Competence</b> <b>Outcomes 8</b>	Demonstrates poor or incomplete understanding of technical content.			Demonstrates some knowledge of the technical content, but explanation lacks adequate depth.		<b>4.4 +/- 0.5</b>	Demonstrates exceptional knowledge of technical content.	
<b>Synthesis of Ideas</b> <b>Outcome 3</b>	Does not have a premise or does not connect issues in essay to concepts in chemical engineering.			Makes connections to chemical engineering concepts, but the connections are weak or implied or premise is weak.			Makes very clear connections between premise and chemical engineering concepts.	<b>5.0 +/- 0.0</b>
<b>Grammar and Structure</b> <b>Outcome 3</b>	Lacks organization or cohesion. Numerous grammatical errors or errors interfere with meaning. Thesis lacking or implied.			Occasional grammar that do not impede meaning. Demonstrates ability to write an essay but lacks cohesion or completeness. Thesis not fully supported.			Demonstrates an ability to effectively communicate in the essay format. Fully supported, clear, concise thesis. Writing style was exceptionally clear and articulate.	<b>4.5 +/- 0.5</b>
Has this cadet demonstrated SO7 (acquiring knowledge)? (Y/N) <b>Y</b>	Comments: <b>Significant improvement from the draft submission. Cadets demonstrated excellent linkage between their topic and chemical engineering (heat &amp; mass transfer) concepts. Overall, well-written and sourced papers. Technical content can continue to be improved.</b>						Assignment used for assessment: (e.g., draft 1 writing assignment 1 in CH485) <b>CH485 Writing FINAL</b>	
	Final Grade: <b>4.7 ± 0.5</b>							

The contemporary issues rubric is designed to assess performance in four skills associated with the ability to acquire new knowledge, namely: rubric row 1 - acquiring knowledge (through development and use of references), rubric row 2 - technical competence of the cadet (as demonstrated with writing skills), rubric row 3 - synthesis of ideas (into a coherent essay), and rubric row 4 - grammar and structure. Each of these skills, taken independently, are associated with written communication (Student Outcome 3). However, the development and blending of these skills into a coherent and well-crafted essay are a measure of acquisition of new knowledge and are thus used by our program to assess Student Outcome 8. Admittedly, this is not a complete measure of a student's ability to acquire new knowledge, only that ability as expressed in an essay. Therefore, we combine this exercise with the other embedded indicators in this section of the report.

Operationally, the contemporary issues rubric is completed by the instructor to award grades to cadets for the writing assignments in this course. In this case, LTC Cowart used one writing assignment in CH485, but completed in two drafts. The average for the draft was  $3.7 \pm 0.80$  and the average on the final was  $4.7 \pm 0.5$ , so they achieved a better average on the final than on the final submission. The final submission was graded against the rubric, with the total average score and average scores per outcome shown in the figure above. Cadets achieved each of the graded rubric rows with proficiency, and instructor comments are included in the screenshots above.

**Level of Achievement of Student Outcome 8:**

The program provides the graduate with a thorough grounding and working knowledge of the chemical sciences, including:

- (8.1) Chemistry.
- (8.2) Material and energy balances
- (8.3) Safety and environmental factors.
- (8.4) Thermodynamics of physical and chemical equilibria.
- (8.5) Heat, mass, and momentum transfer.
- (8.6) Chemical reaction engineering.
- (8.7) Continuous and staged separation operations.
- (8.8) Process dynamics and control.
- (8.9) Modern experimental and computing techniques.
- (8.10) Process design.

***Assessment Instruments and Frequency:***

1. Fundamentals of Engineering Examination, once/yr.
2. Average Course Grades for Chemical Engineering Students, once/yr.

***Assessment Results:***

1. Fundamentals of Engineering Examination, Table 4-14. For the Class of 2021, the breakdown by topic is shown in comparison to the national averages.

<b>Subject</b>	<b>Outcome</b>	<b>Questions</b>	<b>USMA ChE</b>	<b>National</b> (expected level of attainment)
Chemistry & Biology	8.1	7	10.8	9.7±2.8
Material & Energy Balances	8.2	10	8.4	8.9±2.2
Safety, Health, & Environmental	8.3	5	10.3	9.8±3.3
Thermodynamics	8.4	8	9.8	9.3±2.0
Heat Transfer	8.5	8	9.7	9.4±2.5
Fluid Mechanics/Dynamics	8.5	8	9.3	9.4±2.3
Chemical Reaction Engineering	8.6	7	10.1	9.5±2.5
Mass Transfer & Separations	8.7	8	9.4	9.3±2.1
Process Control	8.8	4	10.5	9.6±3.2
Computational Tools	8.9	0	---	---
Economics	8.10	8	11.9	10.1±3.4
Process Design	8.10	7	10.1	9.7±2.5

2. Course grades for the last six years are shown below, Table 4-4 (from Self Study).

Course ↓		Chemical Engineering Student Outcome 8								
		Advanced Chemistry	Mater. & Energy Bal.	Thermodynamics	Transport	Reaction Engineering	Separations	Dynamics & Control	Experiment & Compute	Process Design
		8.1	8.2	8.4	8.5	8.6	8.7	8.8	8.9	8.10
CH383	Organic Chemistry I	3.15								
CH365	Chem. Eng. Thermo.			3.72						
CH362	Mass & Energy Balances		3.64							
CH363	Separation Processes						3.69			
CH364	Chem. Reaction Eng.					3.33				
CH459	Chem. Eng. Laboratory								3.80	
CH485	Heat and Mass Transfer				3.36					
CH400	Chemical Engineering Sem.									
CH402	Chem. Eng. Process Des.									3.33
MA366	Vector Calculus									
ME311	Thermal-Fluid Systems I			3.65	3.65					
ME312	Thermal-Fluid Systems II			3.41	3.41					
CE300	Fund. Eng. Mech. & Des.									
EE301	Intro. To Elec. Engineering									
CH367	Intro. Auto. Process Control							3.35		
Average Grade 2022		3.15	3.64	3.59	3.47	3.33	3.69	3.42	3.80	3.33
Average Grade 2021		2.78	3.54	3.33	3.23	3.31	3.37	3.35	3.67	3.46
Average Grade 2020		3.06	3.53	3.27	3.20	3.38	3.64	3.36	3.53	3.26
Average Grade 2019		3.14	3.63	3.69	3.39	3.67	3.92	3.51	3.52	3.26
Average Grade 2018		2.87	3.72	3.51	3.20	3.66	3.67	3.53	3.42	3.37
Average Grade 2017		3.15	3.21	3.65	3.25	3.66	3.67	3.31	3.54	2.73
<i>Previous 5-year Running Average (expected level of attainment)</i>		3.00	3.53	3.49	3.25	3.54	3.65	3.41	3.54	3.22
Standard Deviation 2022		0.74	0.61	0.66	0.69	0.50	0.58	0.60	0.50	0.50

Table 4-2. Faculty Evaluation of Chemical Engineering Student Outcomes

<b>Chemical Engineering Student Outcomes</b>	<b>Faculty Evaluation</b>
On completion of the chemical engineering program, our graduates are able to:	
1. Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	4.90 $\pm$ 0.32
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.	4.90 $\pm$ 0.32
3. Communicate effectively with a range of audiences.	4.60 $\pm$ 0.52
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.	5.00 $\pm$ 0.00
5. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	4.90 $\pm$ 0.32
6. Develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions.	4.70 $\pm$ 0.48
7. Acquire and apply new knowledge as needed, using appropriate learning strategies.	4.90 $\pm$ 0.32
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.	5.00 $\pm$ 0.00
<b>5- Excellent; 4 – Very Good; 3 – Acceptable; 2 – Weak ; 1 – Poor</b>	

Table 4-3. Advisory Board Evaluation of Chemical Engineering Student Outcomes

<b>Chemical Engineering Student Outcomes</b>	<b>Advisory Board's Evaluation</b>
On completion of the chemical engineering program, our graduates are able to:	
1. Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	4.91 ± 0.30
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.	4.73 ± 0.65
3. Communicate effectively with a range of audiences.	4.64 ± 0.50
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.	4.73 ± 0.47
5. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	5.00 ± 0.00
6. Develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions.	4.82 ± 0.40
7. Acquire and apply new knowledge as needed, using appropriate learning strategies.	4.77 ± 0.41
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.	4.91 ± 0.30
<b>5- Excellent; 4 – Very Good; 3 – Acceptable; 2 – Weak ; 1 – Poor</b>	

**Note: New data from the 2023 advisory board meeting on 14 April 2023 was added on 17 April 2023 for final submission to the AY22 EXSUM.**

Table 4-4. Summary of Chemical Engineering Student Outcomes Performance.

<b>Chemical Engineering Student Outcomes</b>	<b>Program Director's Summary</b>
On completion of the chemical engineering program, our graduates are able to:	
1. Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	5
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.	5
3. Communicate effectively with a range of audiences.	5
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
5. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	5
6. Develop and conduct appropriate experimentation, analyze, and interpret data, and use engineering judgment to draw conclusions.	5
7. Acquire and apply new knowledge as needed, using appropriate learning strategies.	5
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.	5
<b>5- Excellent; 4 – Very Good; 3 – Acceptable; 2 – Weak ; 1 – Poor</b>	

**Note: These PD entries are final values and were updated after the Advisory Board Meeting on 14 April 2023.**



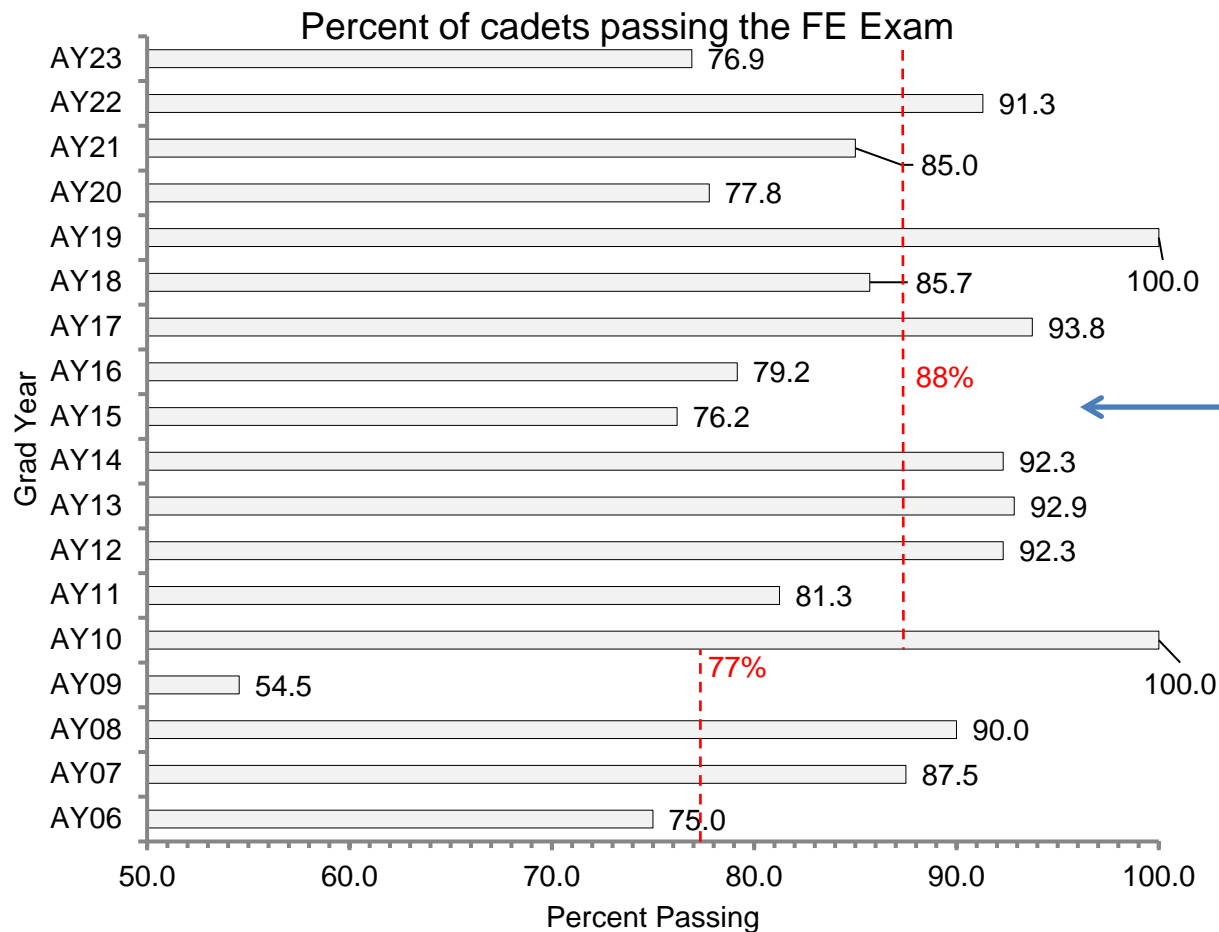
National, (+/- ~1%):

# Fundamentals of Engineering Exam

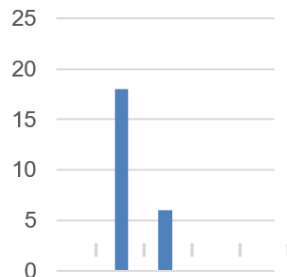
Student Outcome 7: Acquire and apply new knowledge as needed, using appropriate learning strategies

2023	70.2%
2022	70.7%
2021	74.0%
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

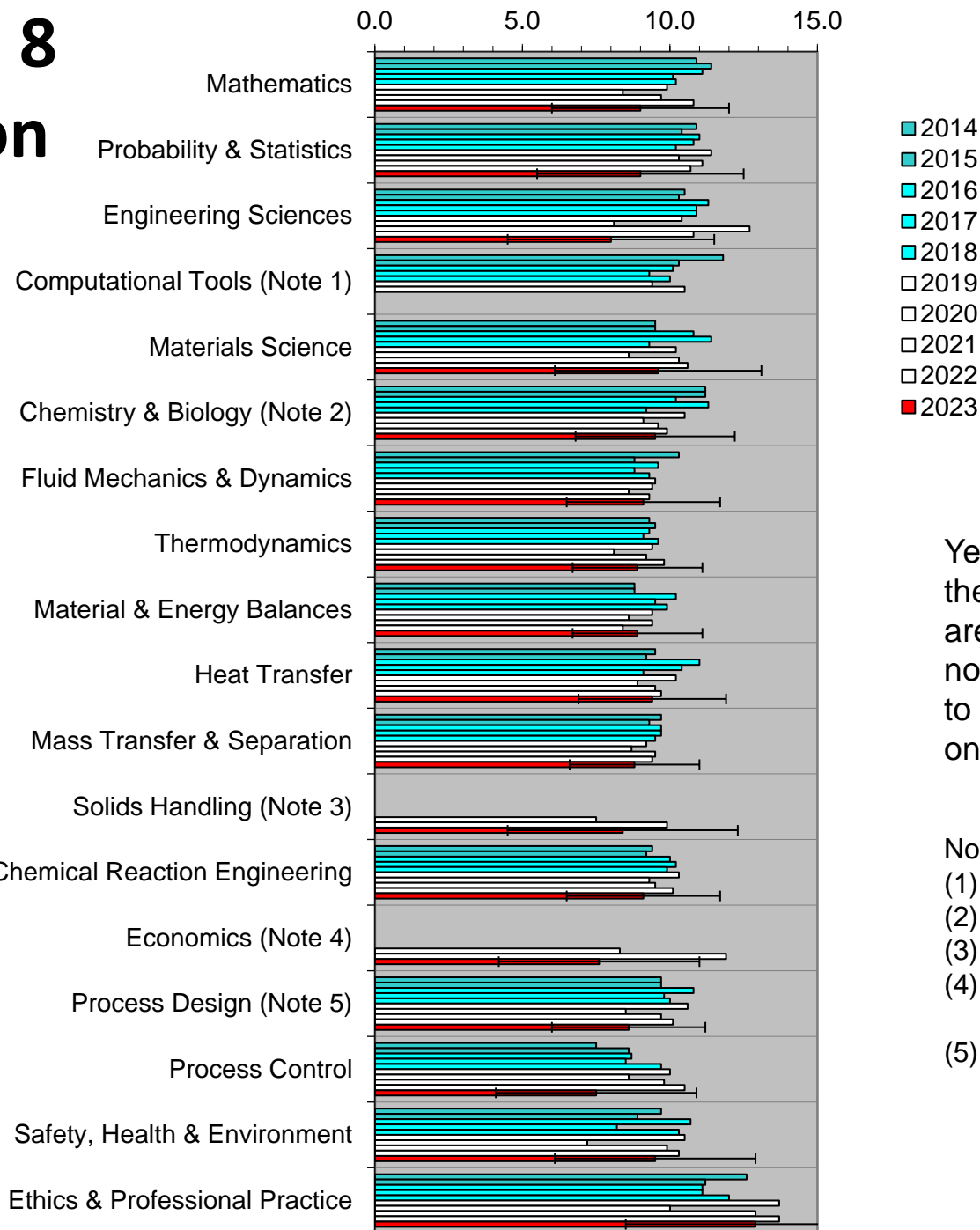


Question 4, Post FEE Survey:  
For the questions on the exam  
that seemed new to you, were  
you able to learn the material  
on the spot?

# Outcome 8 Evaluation

## FEE Results by Topic

AY14 to AY23



Year-to-year variations in the difficulty of the exam are accounted for by normalizing with respect to the national average on the next slide.

### Notes:

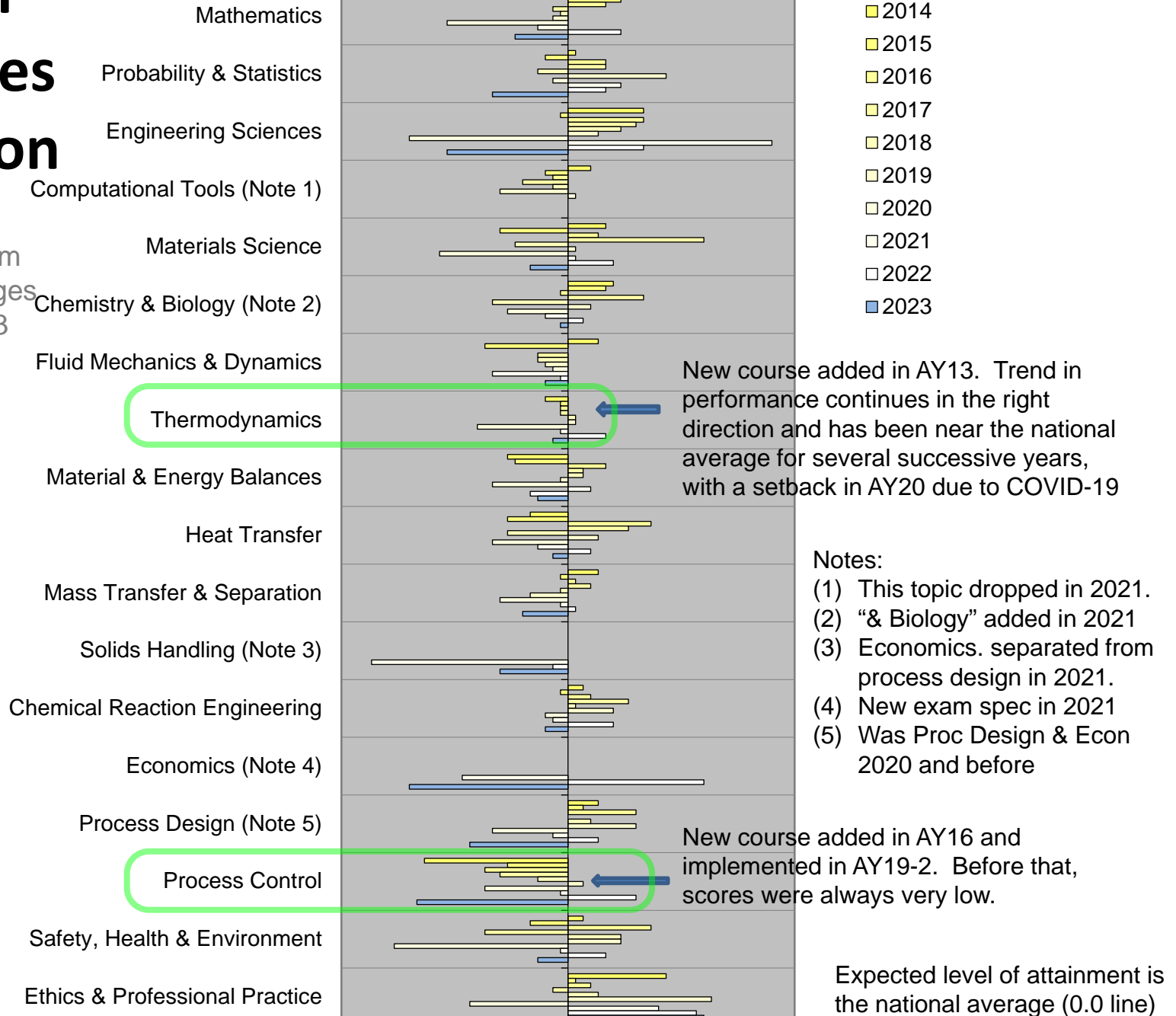
- (1) This topic dropped in 2021.
- (2) "& Biology" added in 2021
- (3) New exam spec in 2021
- (4) Economics separated from process design in 2021.
- (5) Was Proc Design & Econ for 2020 and before

The error bars are the individual standard deviations for the AY23 data.

The average standard deviation over all data is 3.0.

# Topical Outcomes Evaluation

Deviations from National Averages AY14 to AY23



**Enclosure 6 to 2023 Executive Summary of Chemical Engineering Program Assessment:  
Student Outcomes Mapping of APG-What Graduates Can Do (WGCD)  
CEN1 - Class of 2023**

Student Outcome	Communication					Critical/Creative Thinking						Lifelong Learning				Disciplinary Depth				
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	7.1	7.2	7.3	7.4	7.5
1						XX										XX	XX	XX	XX	
2						XX	XX		X		X					XX		X		
3	XX	XX	XX													X			X	X
4						XX												X	X	
5	X		X		X	XX	XX						X			X	X	XX	XX	XX
6										XX					X	XX		X		
7					X	XX				X		XX	XX			X			X	X
<b>Total</b>	XX	XX	XX		X	XX	XX		X	XX	X	XX	XX		X	XX	XX	XX	XX	XX

Student Outcome	Communication					Critical/Creative Thinking						Lifelong Learning				Disciplinary Depth				
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	3.1	3.2	3.3	3.4	7.1	7.2	7.3	7.4	7.5
1						4.11										4.11	4.11	4.11	4.11	
2						4.31	4.31		4.31		4.31					4.31		4.31		
3	4.49	4.49	4.49													4.49			4.49	4.49
4						4.18												4.18	4.18	
5	4.74		4.74		4.74	4.74	4.74						4.74			4.74	4.74	4.74	4.74	4.74
6										4.34					4.34	4.34		4.34		
7					4.38	4.38				4.38		4.38	4.38			4.38			4.38	4.38
<b>Average</b>	4.62	4.49	4.62		4.56	4.344	4.52		4.31	4.36	4.31	4.38	4.56		4.34	4.395	4.42	4.336	4.38	4.53

<b>Grade</b>	<b>A+</b>	<b>A</b>	<b>A-</b>	<b>B+</b>	<b>B</b>	<b>B-</b>	<b>C+</b>
<b>GPA</b>	<b>4.33</b>	<b>4.00</b>	<b>3.67</b>	<b>3.33</b>	<b>3.00</b>	<b>2.67</b>	<b>2.33</b>
<b>Scale:</b>	<b>5.00</b>	<b>4.62</b>	<b>4.24</b>	<b>3.85</b>	<b>3.46</b>	<b>3.08</b>	<b>2.69</b>