Institutional Effectiveness Report
2020-2021

Program: Chemical Engineering BS

College and Department: College of Engineering – Chemical Engineering

Contact: Holly Stretz

Mission: The Department of Chemical Engineering at Tennessee Technological University strives to develop the 21st Century Renaissance Engineer through development and implementation of novel learning environments anchored by the award-winning Renaissance Foundry Model. The foundation of this platform is rooted in the guidelines provided by the National Academy of Engineering's Vision for the Engineer of 2020. Educational protocols within the department are consistent with the mission and vision statements given below:

The Mission of the Department of Chemical Engineering is to prepare relevant and adaptive chemical engineers in state-of-the-art areas by emphasizing real-world problem solving and critical thinking skills. The Vision of the Department of Chemical Engineering is to be a recognized leader in chemical engineering education through excellence in teaching, research, and service.

Program Goals

PG 1. *Be recognized as real-world problem solvers*: the graduates of our program will obtain positions such as plant process engineer, design engineer, group leader, production engineering, sales engineer.

PG 2. *Be recognized as critical thinkers*: the graduates of our program will demonstrate that they consistently make informed decisions through a process wherein they utilize critical thinking skills.

PG 3. *Continue their formal education*: the graduates of our program will demonstrate that they have continued their education beyond the BS through some form of professional development (not necessarily leading to another degree) or will have graduated from a professional school with an MS, PhD, MD, JD or similar degree.

PG 4. *Work at the frontiers in the profession of chemical engineering*: the graduates of our program will utilize and apply technologies such as bio materials, nano- and micro-systems, multi-scale analysis, informatics, group dynamics and, multi-media.

Student Learning Outcomes

SLO 1. *FORMULATE & SOLVE* – an ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics

SLO 2. *DESIGN for NEED, SAFETY, GLOBAL & SOCIAL FACTORS* – an ability to apply engineering design to produce solution that meet specific needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

SLO 3. *COMMUNICATE* – an ability to communicate effectively with a range of audiences.

SLO 4. *ETHICS* – an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

SLO 5. *TEAMS* – an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives.

SLO 6. *EXPERIMENT, ANALYZE & INTERPRET* – an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions.

SLO 7. *KNOWLEDGE ACQUISITION* – an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

A departmentally developed curriculum map can be found in Appendix 1 that shows the connections between courses and student learning outcomes.

Mapping of Student Outcomes and Program Educational Objectives.

	Program Educational Objectives			
Student Outcomes	**Real World Problems Solver (RWPS)**	**Critical Thinker (CT)**	**Continue Formal Education (CFE)**	**Work at Frontiers in Chemical Engineering (FChE)**
1 Formulate	X	X		X
2 Design	X	X		X
3 Communicate	X			X
4 Ethics	X	X		X
5 Teams	X			X
6 Experiment	X	X		X
7 Knowledge	X	X	X	X

Assessment Methods:

All assessments are completed on a semester or annual basis, unless otherwise noted in the description of a tool.

1. *Senior Survey* (Annually). The senior survey provides the opportunity for student feedback (anonymously) on different aspects of the program student outcomes, the CHE curriculum, and the student's experiences while at TTU. In addition, a number of questions are directly related to specific SOs. In this way, feedback is gathered from the student sector of our constituency on both student outcomes and program educational objectives.

2. *External Review of Senior (capstone) Design Projects* (Each Semester). External evaluators are invited to access the quality of the Senior Design Projects and to provide feedback on the capstone Design course. The evaluators ask questions of the team members and provide feedback on the technical quality of the projects and oral presentations using an established ABET Criteria-based rubric.

3. *Course Level Assessment*: (Every term a course is taught). The Department uses selected courses to learn about student performance at the different levels of the curriculum, refer to the current "Articulation Matrix" table shown two pages from here. Course-level assessment is done every term in which the course is taught and an Overview is assembled every third year. Those overviews are used to continuously improve the course and curriculum as a whole and are discussed with the departmental faculty and appropriate actions taken.

4. *Co-Op Report Assessment*: (Semi or annually). The Department uses a survey report directly written by the students' supervisor at the co-op site to learn about important student competences. The questionnaire requires responses for each of the 1 through 7 student outcomes.

5. *CHE External Advisory Board, BOA*, (Annually). The CHE External Advisory Board consists of between 18 members selected primarily from employers of our students, related industries and accomplished alumni. BOA is an advisory group which provides input and feedback on various curricular and accreditation matters (ABET, SACS, THEC Graduate Program Review). Some BOA members also regularly serve as the External Evaluators for the Senior Design Projects. The BOA bi-annually meets with the students, in the absence of faculty, to gather input regarding student impressions across the 1 through 7 student outcomes, but not necessarily focusing on any particular outcome. The data is gathered during a one-hour meeting in an informal setting and is communicated likewise to the faculty during an oral briefing session. At times the BOA may report in writing regarding select items, but that decision is left to them.

Assessment processes used, the frequency of application and expected level of attainment.

	Assessment Process	Student Outcomes*	Assessment Frequency	Expected Level of Attainment
	Processes for Student Outcomes Assessment			
1	**Senior Survey**	a-k	A population of seniors is surveyed once every third year.	Likert ≥3/5
2	**External Assessment of Senior Design Projects**	a, c, d, e, g, h, k	Design II projects are externally assessed in the Spring of each year.	>60% (>70%)
3	**Course-Level Assessments**	a-k	Course-Level Assessments are completed for select courses every term in which they are offered.	>60% (>70%)
4	**Co-Op Employer Assessments**	a-k	Co-Op employer assessment data is gathered for every student participating in co-op at the end of their internship. The collective data is evaluated every third year.	Likert ≥3/5
5	**External Advisory Board (BOA) Assessment**	a-k	The BOA gathers student feedback bi-annually and reports it to the department.	Generally Positive Qualitative Assessment

Expected Level of Attainment: The expected achievement outcomes for course-level assessments may vary and are the purview of the instructor of record for particular assessed courses. In general, attainment levels that are direct measures of student achievement are considered minimally acceptable if the student achieves 60% and if the student body achieves 70% on the average. Where Likert-based questionnaires are used, a score of three out of five, with five being the most positive score is generally considered the minimum expected outcome. Where qualitative inputs are provided, as is the case of

input from the BOA, generally positive feedback is considered the expected minimum outcome. As an example, generally positive remarks include those regarding the program from the student body in communication to the BOA (e.g., “we feel prepared in design” or “our lab experience helped me to relate to the theory” or “classes are difficult, but fair,” etc.). Anything less than generally positive feedback would be discussed and considered by the faculty.

Results:

Results (for Critical Thinking)--Program Goal 2 and Student Learning Outcomes 1, 2, and 6: For 2020-2021, 56 students in CHE took the California Critical Thinking Skills Test (CCTST) with a mean score of 79.3. This score is similar to that from the converted scores from the previous two years (2018-2019: 81.0, n = 42 and 2019-2020: 79.0, n=48).

Source: https://www.tntech.edu/iare/assessment/criticalthinking.php

Results (from Board of Advisors' Meetings)--Program Goals 1-4: The BOA meetings are held annually. The BOA generally documents its findings in the form of an Executive Summary. Their findings regarding student success and satisfaction are reported there. Recommendations are used specifically as feedback into the program's curricular change process; however, such are rarely made by the BOA. Broader programmatic issues are typically identified by the BOA and are used to influence elements, including but not limited to faculty numbers and institutional support.

At the BOA meeting in November 2020, the following topics were discussed:

- Options related to a potential pilot plant install
- Department updates/needs
- Upcoming ABET review

In addition, the BOA had conversations with the Dean of the College of Engineering. Interactions with faculty and staff in the department as well as undergraduate and graduate students were also a major aspect of the meeting.

Results (from Co-Op Performance Assessments)--Program Goal 1 and Student Learning Outcomes 1, 3-5, and 7: For the Summer 2020 through Spring 2021 semesters, nine CHE students completed a total of 13 co-op semesters. Each student is assessed by their on-site supervisor via a survey. This Co-Op survey includes 12 questions which per the new ABET Student Learning Outcomes map to Outcomes 1, 3-5, and 7. Survey questions are ranked on a 1 (lowest) to 5 (highest) scale. Our rubric is that no student receives a score lower than 3. On average, scores for this reporting period are between 4 and 5 for most students with an occasional lower score. We continue to conclude that co-op employers are satisfied with our students’ performance across the board.

SLO 1. *FORMULATE & SOLVE* – an ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		-	**29%**	**N/A**
Course-Level Assessments	CHE 4210 Kinetics (≤ 70%)	-	**+**	**N/A**
	CHE 4540 Controls (≤ 70%)	**78%**	**75%**	**69%**
Co-Op Employer Assessments (Likert≤3)		**4.0**	**4.0**	**4.0**

+ Some students scored below minimum rubric of 60% but class exceeded overall 70% threshold.
Note: Yellow shading represents a "watch, possibly act" while green represents value meets threshold.

SLO 2. *DESIGN for NEED, SAFETY, GLOBAL & SOCIAL FACTORS* – an ability to apply engineering design to produce solution that meet specific needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		-	**0%**	**N/A**
Course-Level Assessments	CHE 3121 Trans. Sci. II (≤ 70%)	**79%**	**74%**	
	CHE 4410 Design I (≤ 70%)	**84%**	**84%**	**94%**
	CHE 4420 Design II (≤ 70%)	**83%**	**90%**	**93%**
Co-Op Employer Assessments (Likert≤3)		**4.0**	**4.3**	**4.2**

SLO 3. COMMUNICATE – an ability to communicate effectively with a range of audiences.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		-	**22%**	**N/A**
External Assessment of Capstone Labs (team average ≤ 70%)		-	**89%**	**94%**
Course-Level Assessments	CHE 3121 Trans. Sci. II (≤ 70%)	-	**87%**	
	CHE 4210 Kinetics (≤ 70%)	-	**84%**	
	CHE 4240 Capstone Lab (≤ 70%)	-	**90%**	**80% (Median)**
	CHE 4410 Design I (≤ 70%)	**86%**	**88%**	**90%**
	CHE 4420 Design II (≤ 70%)	**91%**	**90%**	**95%**
	CHE 4540 Controls (≤ 70%)	**86%**	**92%**	**94%**
Co-Op Employer Assessments (Likert≤3)		**4.5**	**4.0**	**4.0**

SLO 4. ETHICS – an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgements, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		-	**6%**	**N/A**
Course-Level Assessments	CHE 4420 Design II (≤ 70%)	-	**93%**	**96%**
	CHE 4540 Controls (≤ 70%)	**86%**	**92%**	**95%**
Co-Op Employer Assessments (Likert≤3)		**4.1**	**4.5**	**4.2**

SLO 5. *TEAMS* – an ability 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 Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		**-**	**0%**	**N/A**
External Assessment of Capstone Labs (team average ≤ 70%)		**-**	**89%**	**94%**
Course-Level Assessments	CHE 4240 Capstone Lab (≤ 70%)	-	**92%**	**^**
	CHE 4420 Design II (≤ 70%)	-	**93%**	**94%**
Co-Op Employer Assessments (Likert≤3)		**4.2**	**4.7**	**4.3**

^Team work was mandatory to complete the course requirements. The wide spectrum of individual contributions to the team reflects the expanse of the abilities of our chemical engineering students in the program and the additional course burdens experienced by the students during the final semester of their senior year. There were a few situations in which team dynamics were strained at one or more points in the semester which required instructor intervention, but overall team performance was strong.

SLO 6. EXPERIMENT, ANALYZE & INTERPRET – an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		**-**	**0%**	**N/A**
External Assessment of Capstone Labs (team average ≤ 70%)		**-**	**89%**	**94%**
Course-Level Assessments	CHE 4210 Kinetics (≤ 70%)	-	**87%**	
	CHE 4240 Capstone Lab (≤ 70%)	-	**94%**	**#**

#All teams performed well in linking their projects to a core chemical engineering class/equation, developing an experimental procedure, and selecting an appropriate analysis method. However, any disparity in team performance became more abundant in the elements that required higher levels of analysis and interpretation. Half the class excelled in calibrating their analysis method, however the 1st quartile was zero. Applying a chemical engineering equation to facilitate interpretation of their experimental results suggest that only half the class was able to apply the chemical engineering concepts they had been taught throughout their time in the program to a real-world problem. In general, the student teams were able to make factual interpretations of their project results, extracting meaningful results from their data.

SLO 7. KNOWLEDGE ACQUISITION – an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**	**2019-20**	**2020-21**
Senior Survey (≥30% of responses below rubric)		**-**	**100%**	**N/A**
Course-Level Assessments	CHE 3121 Trans. Sci. II (≤ 70%)	-	**75%**	
	CHE 4410 Design I (≤ 70%)	-	**78%**	**N/A**
Co-Op Employer Assessments (Likert≤3)		**4.5**	**4.5**	**4.3**

Modifications for Improvement (from Course Level Assessments):

CHE 4240: Prior to this course being taught again in the Spring of 2022, students should be given additional time to select a project and consider the design constraints during the Fall of 2021. Further, project lists should be prepared and corresponding project descriptions developed based on feedback and interactions amongst faculty in the department as well as in consultation with potential external sponsors.

CHE 4410: Since the new ABET Criterion 3.2 for design includes many sub-elements that must be specifically assessed, the new assessment strategies include explicit tasks within projects and exams to identify Criterion 3.2 sub-topics, e.g., Synthesis (Syn) and Risk Assessment (Risk), etc. The collective student body performed very well in all areas this term even under extraordinary conditions associated with the global pandemic. The instructor taught all courses on-line and posted all class sessions for later student use. The instructor was available to students on-line at almost any time and upon request by the students. The final outcomes were very good from a class average perspective. Individual shortfalls, however, particularly in the area of "risk analysis" were noted with 20 of 62 students falling below threshold. A bit of emphasis on identification and definition of "risks" should be included in the course next term above what was done this term.

CHE 4420: During the Spring of 2021, the current assessment period, a new experiment in Design II was considered. Motivated by the College of Engineering's (COE) effort to bring more innovation and authentic project experience to its students, the Department of Chemical Engineering (CHE) agreed to pilot the use of industrial partners, i.e., Industrial "Academy" Instructors, to coach design teams. The 2021 Academy consisted of eight prior TTU CHE graduates all of whom had taken the Design sequence with the current design course instructor. A number of workshops were arranged to train the Academy participants in how to score projects, manage project teams, and report findings in accordance with departmental ABET expectations. Score sheets and detailed rubrics were distributed and instructions on how to use them were given in the workshops. The course instructor was also on-call to the Academy participants throughout the term. The Academy experiment should be continued for at least one more term to gather further input from the Academy participants and students.

CHE 4540: A stronger support to the instructor is desired from the TAs, particularly related to the completion of projects and students working in teams. The TA must be knowledgeable and have more interactions with the teams during the course of the project. This should be communicated to the TA in

the beginning of the semester. It was also suggested that a lab component would be tremendously helpful to improve students' learning experience.

Towards a focus on benchmarking, the completion of a "major field test" by our graduating seniors is a new requirement. The topic has been discussed significantly at recent departmental meetings where we discussed and voted that Design II rubrics (from the CHE 4420 course) will be the basis for our major field test, pending evaluation by two external reviewers to be determined.

Appendices

1. Curriculum Map

Appendix 1: Curriculum Map

Articulation Matrix Mapping of Student Outcomes and the Courses of the Curriculum

Course No.	Description (Responsible Faculty)	Required or Elective (R or E)	Mapping to Student Outcomes (SO)						
			1 Formulate & Solve	2 Design for Need, Safety, Global & Societal	3 Communicate	4 Ethics in Global & Societal Context	5 Teams	6 Experiment Analyze & Interpret	7 Knowledge Acquisition
CHE 1010	Intro. to CHE (BG)	R							
CHE 1020	CHE Process., Prod. & Ethics (SJ)	R							
CHE 2015	Chem and Biol Eng. Anal. I (LC)	R							
CHE 2020	Chem and Biol Eng. Anal. II (LC)	R							
CHE 3010	Thermo of Chem. Proc. (VP)	R							
CHE 3111	Cond., Rad., Diff. (SJ)	R							
CHE 3735	CHE Operations (CR)	R							
CHE 3021	CHE Thermodynamics II (LZ)	R							
CHE 4131	Diff. & Mass Transfer (JRS)	R							
CHE 3121	**Fluid Dynamics (SJ&PA)**	**R**		**ABET**	**ABET**				**ABET**
CHE 4210	**Kinetics (CR)**	**R**	**ABET**		**ABET**			**ABET**	
CHE 4240	**Capstone Lab (HS)**	**R**			**ABET**		**ABET**	**ABET**	
CHE 4410	**Capstone Design I (JJB)**	**R**		**ABET**	**ABET**				**ABET**
CHE 4420	**Capstone Design II (JJB)**	**R**		**ABET**	**ABET**	**ABET**	**ABET**		
CHE 4540	**Proc. Dyn. & Controls (VP)**	**R**	**ABET**		**ABET**	**ABET**			

ABET – Assessed Student Outcome for ABET continuous improvement purposes, courses shown in **bold.**