Institutional Effectiveness Report
2018-19

Program: Chemical Engineering BS

College and Department: College of Engineering – Chemical Engineering

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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 (PEO's)

PEO 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.

PEO 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.

PEO 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.

PEO 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's)

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

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.

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

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.

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.

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

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

Note: Starting Spring 2019, the student outcomes have transitioned to new ABET Criterion 3.1 through 3.7.

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 attached table. 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 to 24 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: Students taking CHE 3111 (Heat Transfer) and CHE 3121 (Fluid Mechanics) during the 2018-19 academic year were assessed for critical thinking skills via the Critical thinking Assessment Test (CAT) which is an NSF-supported instrument developed at TTU and based on four broad aspects of critical thinking: evaluation/interpretation of information, problem solving, creative thinking, and effective communication. The test, designed to be interesting and engaging for students, has questions derived from real world situations. Most of the questions require short-answer essay responses, and a detailed scoring guide as well as grader training, and multiple graders help insure good scoring reliability. While various assessment designs are possible, a pre- and post- exam strategy was used for these two courses. Specifically, given that the heat transfer course is taken in the first semester of the junior year and the fluid mechanics course is taken during the second semester of the junior year, all students in the heat transfer course took the CAT at the beginning of the fall semester. Then, roughly half of these students took the test at the end of the fall semester (thus providing an indicator of improvements in critical thinking during this semester) while the other half of students took the test again at the end of the fluid mechanics course. Students in the heat transfer course who took the test pre and post that semester (n=25) showed an average, statistically significant increase in their "CAT Total Score" which increased from 16.80 to 18.64. Students who had taken both the heat transfer and the fluid mechanics courses and took the pre-test at the beginning of the fall semester and the post test at the end of the spring semester (n=24) showed an increase in the CAT Total Score from 18.60 to 21.15.

Results (from Alumni and Employer Surveys)--Program Goals 1-4: A new strategy of survey collection has been decided upon that leverages the CHE Board of Advisors (BOA) which includes program alumni and employers. The new survey will contain questions directly related to the attainment of Program Goals. Written comments will also be collected.

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.

In the November 2018 meeting with the BOA, faculty reported the following regarding the undergraduate curriculum:

- CHE is traveling a trajectory towards innovation with impact: Efforts include but are not limited to engineering at the borders of nursing and CHE, a focus on entrepreneurship, and an increase of students involved in undergraduate research.

- The department implements the Renaissance Foundry Model across the curriculum: As a result, the department displays a collaborative-centered and team-based approach to student learning with closely-integrated facilitator-based discussions and guidance.
- Commendations for the department: The recent Eagle Works Competition was won by CHE students, the undergraduate students have led us to another title as the Best Darn Major, and faculty mentoring has led to increased involvement in undergraduate research making CHE the leader of such efforts within the College of Engineering.
- Curriculum grants are allowing development of updated experiential learning opportunities for students: Creative inquiry through immersion experiences intended to enhance problem-identification strategies and prototype development to address specific learning challenges became the focus across three courses within the undergraduate curriculum after approximately $20,000 in funding was awarded via the TTU Enhanced Discovery through Guided Exploration (EDGE) Creative Inquiry Curriculum Grant Program. Such experiences offered students a more systematic approach to problem-solving strategies, ultimately enhancing their understanding of course material in an integrated fashion across the curriculum.

Following discussions, the Board provided the following feedback to the faculty regarding the undergraduate curriculum:

- The Board is excited by the leadership demonstrated by our students in the winning of the Best Darn Major award for five (four consecutive) years.
- Increased efforts with respect to faculty relationships with local industry are recommended to increase the number of companies recruiting CHE students at the career fairs as well as increase the number of alumni involved in classroom activities.
- A more systematic blending of programming is necessary across the curriculum.

Results (from Co-Op Performance Assessments)--Program Goal 1 and Student Learning Outcomes 1, 3-5, and 7: The Co-Op survey includes 12 questions. 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 are between 4 and 5 for most students with an occasional lower score. We conclude that co-op employers are satisfied with our students' performance across the board.

Results (from Chair Debriefing)--Student Learning Outcomes 1-7: Regarding feedback during Chair debriefings (and following input from the BOA), the feedback of the BOA indicated that the experiences in laboratories are going in the right path for correction and satisfaction of the students. The Department is still monitoring this situation very closely with the help of the Capstone Lab Coordinator. The Department continues monitoring and receiving feedback from the students for courses that were indicated as a concern.

Student Outcome 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**
Course-Level Assessments	CHE 4540 Controls (≤ 70%)	**78%**
Co-Op Employer Assessments (Likert≤3)		**4.0**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)		**none**
OVERALL INTERPRETATION		

Course-level results for Student Outcome (1) showed that students are collectively at threshold, but that many individual students scored below the minimum expected threshold. This differed from students' self-opinion of their skill level which met the threshold with 12 of 17 responses above threshold on the most recent Senior Survey. Co-Op employers also responded positively to questions regarding student abilities to solve complex problems, their responses being directed more at cognitive processes rather than computational skills. BOA feedback for this outcome was unremarkable. Collectively, the strong evidence that a significant number of students scored below the minimum threshold prompted an overall interpretation of "Watch, possibly act (yellow)" for this outcome.

Student Outcome 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**
Course-Level Assessments	CHE 3121 Trans. Sci. II (≤ 70%)	**79%**
	CHE 4410 Design I (≤ 70%)	**84%**
	CHE 4420 Design II (≤ 70%)	**83%**
Co-Op Employer Assessments (Likert≤3)		**4.0**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)		**none**
OVERALL INTERPRETATION		

The collective feedback for level of attainment for Student Outcome (2) was very consistent and indicated that students are above threshold. Course-level assessments in CHE 3121 and the design sequence CHE 4410 and 4420 were above threshold. Seniors also self-assessed very positively when asked a collection of 25 questions regarding design competency. Likewise, Co-Op employer responses to a survey question regarding Student Outcome (2) were above threshold. BOA feedback was silent. This outcome was ranked as "Meeting rubric, no action necessary at this time".

Student Outcome 3: COMMUNICATE – an ability to communicate effectively with a range of audiences.

Assessment Process (threshold Student Outcome attainment level)		**2018-19**
External Assessment of Capstone Labs (team average ≤ 70%)		-
Course-Level Assessments	CHE 3121 Trans. Sci. II (≤ 70%)	-
	CHE 4410 Design I (≤ 70%)	**86%**
	CHE 4420 Design II (≤ 70%)	**91%**
	CHE 4540 Controls (≤ 70%)	**86%**
Co-Op Employer Assessments (Likert≤3)		**4.5**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)		**none**
OVERALL INTERPRETATION		

Students self-assessed rather critically, indicating that they are not satisfied and not confident in their ability to communicate; 50% of their responses to eight individual questions on the Senior Survey were below threshold. This is somewhat surprising since course-level assessments and Co-Op employers indicated otherwise. Student Outcome (3) associated with communications is the most assessed outcome; being assessed in each of the six articulation matrix courses as well as by external examiners of Senior Design projects, Co-Op employers and considered by the students and BOA. All six course-level assessments indicated good written performance and oral presentation performance across various audiences, e.g. writing for an executive or another engineer or presenting to technical clients or scientific review board. BOA input is silent on this topic, i.e. students have not discussed this topic with the Board.

Student Outcome 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**
Course-Level Assessments	CHE 4540 Controls (≤ 70%)	**86%**
Co-Op Employer Assessments (Likert≤3)		**4.1**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)		**none**
OVERALL INTERPRETATION		

Seniors conclusively felt that they are receiving adequate training in professional ethics, responding positively to 17 of 18 questions regarding Student Outcome (4). Likewise, Co-Op employers on three separate survey questions indicated that students have good knowledge of their professional ethical

responsibility as an engineer. The BOA has been silent on this topic. Course-level assessments also indicated that students have achieved above threshold scores for professional ethics when assessed. Finally, ethical behavior has notably improved among the student body with numbers of misconduct filings approaching zero.

Student Outcome 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**
Co-Op Employer Assessments (Likert≤3)	**4.2**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)	**none**
OVERALL INTERPRETATION	

Student self-assessments, Co-Op surveys and course-level assessments all indicated that collectively students are obtaining and achieving threshold-level outcomes for Student Outcome (5) related to teamwork. Unfortunately, these assessments do not see the entire picture on their own. Peer assessments used in CHE 4410 and CHE 4420 indicated that some students are not participating fully and in fact are disruptive to team performance. Recent data showed that as many as 15% of students fall below a minimally acceptable level of team contribution when assessed by peers. While other assessment indicated strong team performance, including Co-Op assessments, and good knowledge of teamwork practices, this outcome was scored as “Watch, possibly act (yellow)”.

Student Outcome 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**
Senior Survey (≥30% of responses below rubric)	**-**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)	**minor**
OVERALL INTERPRETATION	

Student survey and course-level assessment findings all indicated that students are meeting thresholds for Student Outcome (6) related to experimentation. These findings, however, are superseded by other input from the students which was communicated to us via the Board of Advisors (BOA). Students indicated that CHE 4240, Capstone Lab, was a great deal of work for 1 credit hour. This conversation had been on-going for years in the Department. As a result, this Student Outcome was assessed as “Watch, possibly act (yellow)”.

Student Outcome 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**
Senior Survey (≥30% of responses below rubric)	**-**
Co-Op Employer Assessments (Likert≤3)	**4.5**
Board of Advisors (BOA) Feedback (qualitative, no negative feedback)	**none**
OVERALL INTERPRETATION	

Surprisingly, students' self-assessments for Student Outcome (7) indicate that they conclusively felt they are not obtaining an acceptable level of training. Given that students say they are unprepared in these areas, we have chosen to score Student Outcome (7) as "watch, possibly act (yellow)". This decision supersedes good indications from Co-Op employers and good course-level outcomes. The surprising results from the Senior Survey must be investigated. A survey will also be done in 2020 to revisit this outcome and students will be asked to provide input at the Fall 2020 BOA meeting. The BOA feedback is thus far silent on this topic.

Modifications for Improvement:

SLO 1 - Use of Engineering Tools

While students are collectively at threshold, a significant fraction of individual students have poor skills in the area of problem solving with programmable platforms, e.g. MatLab, MathCad, C++, etc. This realization became apparent to the instructor of record for Design I and II who frequently works one-on-one with many students on such programming skills. His individualized training thus provided a basis for direct assessment of student skills and levels of proficiency. Beginning with the Fall 2019 offering of Design I, individual assessment of problem-solving skills using software platforms will be implemented to provide individual feedback and provide an individual level of assessment.

SLO 2 & SLO 7 – Global and Contemporary Context; Knowledge Acquisition

The Student Survey Assessment Process has consistently indicated that students feel that their exposure to topics related to global and contemporary topics as well as life-long-learning skills is limited. For Fall 2019, we will renovate CHE 1010, Introduction to Chemical Engineering, to introduce more opportunities for freshmen students to consider the process industry in relevant contexts. This early introduction to CHE in a more applied way will fuel student interest in the global and contemporary context and for the need for continued education. The plan is to assess the effectiveness of the CHE 1010 course restructuring by looking at course-level Assessment Process outcomes for CHE 4420 beginning in the Spring of 2021.

SLO 5 - Teamwork

Based on peer assessments used in CHE 4410 and CHE 4420 that indicated that some students are not participating fully and in fact are disruptive to team performance, a second and significant effort to improve teamwork was implemented in our CHE 3121 Transfer Science II course. The laboratory section

was restructured to include student training in performing as functional-based teams during hands-on integration of course material via the creation of a prototype of innovative technology. The training consisted of multiple activities in which students acquire and apply (or transfer) knowledge regarding the attributes of a functional team, including but not limited to the need for a strong social contract and assessment of the contracts built. Even after this level of intensive and systematic teamwork training, when placed in a new environment, i.e. CHE 4410, this training does not seem to translate into improved team behaviors. The Department is evaluating and developing additional strategies in an effort to make substantive improvements in student application of skills acquired across the curriculum.

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.**