

## Chemical Engineering MS: 2019-2020

### Definition of Unit

**Providing Department:**

Chemical Engineering MS

**Department/Unit Contact:**

Holly Stretz, Cindy Rice

**Mission/Vision Statement:**

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.

<from [https://www.tntech.edu/engineering/programs/che/about\\_che.php](https://www.tntech.edu/engineering/programs/che/about_che.php)>

The Department of Chemical Engineering at Tennessee Tech blends scholarship and research with advanced course work, providing excellent opportunities to graduate students to work towards solving some of the many global challenges faced by society. Our program offers an MS [thesis and non-thesis] in Chemical Engineering and a PHD in Engineering with a specialization in Chemical Engineering. The relatively small size of the program and friendly campus atmosphere promote close interaction among students and faculty. Research is sponsored by federal agencies (such as NSF) as well as state and private sources among others. As we have been moving to a higher level of research excellence, students are receiving national accolades and some are entering the program with prestigious international fellowships from their governments and/or from international organizations. Faculty members work closely with colleagues in Electrical Engineering, Civil and Environmental Engineering, Mechanical Engineering, Chemistry, Biology, and Manufacturing and Engineering Technology at TTU, as well as maintain strong collaboration with TTU's Centers of Excellence and other leading institutions and national laboratories to build a unique and effective environment for graduate student research, learning, and well-rounded training.

<from [https://www.tntech.edu/engineering/programs/che/grad\\_che.php](https://www.tntech.edu/engineering/programs/che/grad_che.php)>

These activities are consistent with the TTU mission and vision which are posted at the following website (<https://www.tntech.edu/about/mission.php>).

## **Program Goal 1: Develop and Maintain a Sufficient Number of Graduate Students**

### **Define Goal:**

**Program Goal 1:** Develop and maintain a competitive graduate student body in the range of 3-4 graduate students per faculty member with more than half of them pursuing a PHD.

### **Intended Outcomes / Objectives:**

Currently (per Fall 2019 census for the MS program and departmental data for the PHD program), the program shows 46% (13 students) are enrolled at the MS level and 54% (15 students) at the PHD level, the latter of which reflects four students who completed their MS in CHE at TTU and are enrolled in the PHD program and another six students who completed their BS in CHE at TTU and are enrolled in the direct-admit PhD program. With nine tenured or tenure-track faculty and one instructor in the department, the average number of graduate students per faculty is 2.8.

## **Program Goal 2: Maintain a Diverse Graduate Student Body**

### **Define Goal:**

**Program Goal 2:** Maintain a diverse graduate student body consisting of domestic and foreign students including minorities and individuals of underrepresented groups.

### **Intended Outcomes / Objectives:**

Currently (per Fall 2019 census), 43% overall (46% at the MS level) of the graduate students are female graduate students, and there are graduate students from the USA, Bangladesh, Brazil, China, Hungary, India, Iran, Iraq, Nepal, Nigeria, and Taiwan.

### **Program Goal 3: Provide Rigorous, Interdisciplinary, and Current Training in CHE**

#### **Define Goal:**

**Program Goal 3:** Provide students with a rigorous, interdisciplinary, and current training through both course work and research projects in relevant areas of modern chemical engineering.

#### **Intended Outcomes / Objectives:**

Students' programs of study (on file in the CHE office and in the College of Graduate Studies) reflect comprehensive course work within and beyond CHE, and publications as well as conference presentations reflect relevance of the research efforts to modern problems.

### **Program Goal 4: Provide a Meaningful Environment for Student Growth**

#### **Define Goal:**

**Program Goal 4:** Provide a meaningful environment for student growth in cultural, professional and academic aspects including opportunities to develop as a future faculty member in an academic department.

#### **Intended Outcomes / Objectives:**

All graduate students in the CHE graduate programs are encouraged to participate in CEGRA which provides extensive opportunities for personal enrichment. Many graduate students, especially MS-CHE students, have opportunities to serve as TA's.

### **Program Goal 5: Demonstrate Peer-Reviewed Scholarship**

#### **Define Goal:**

**Program Goal 5:** Demonstrate scholarship through peer-reviewed/archival publications, externally sponsored projects and presentation in national and international scientific meetings.

#### **Intended Outcomes / Objectives:**

This information is readily measured by review of faculty CV's and through interactions observed between TTU CHE faculty and students at regional and national conferences.

## **Program Goal 6: Optimize Graduate Student Time to Graduation**

### **Define Goal:**

**Program Goal 6:** Optimize graduate student time to graduation by providing courses and advising that facilitates student completion of the MS degree within a desired two-year window.

### **Intended Outcomes / Objectives:**

Course offerings are routinely evaluated, and courses are offered at a frequency that enables students to graduate in-line with the stated goal. Each student is assigned an advisor who routinely meets with the student.

## **Student Learning Outcome 1: Acquisition of Research Skills**

### **Define Goal:**

Aid students in acquiring/developing research skills

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 1 (Expectations):** All MS-thesis students must demonstrate knowledge and proficiency in the method of scientific inquiry. Development of these skills is demonstrated via numerous means including: (1) satisfactory progress towards completion of the thesis research project as measured by grades posted during semesters in which a graduate student signs up for the CHE 6990 (Research and Thesis) course; (2) completion of a written thesis with appropriate content and presentation format that is accepted by the student's advisor, the thesis committee, and the Dean of the College of Graduate Studies; (3) oral presentation and defense of the research project in front of the student's thesis committee, student peers, and the general chemical engineering faculty and (4) remediation of any issues raised by either the committee at the time of signing of the program of study or at the time of completing the thesis/defense.

Students in the department's non-thesis MS program (including students in the direct-admit PHD program and those pursuing only the MS degree) complete a project course (CHE 6970) in which independent, but guided work on a topic of interest and relevance to their program of study is conducted. Project approaches and outcomes are presented to members of the student's advisory committee upon completion of the project.

## **Student Learning Outcome 2: Content Knowledge Gains**

### **Define Goal:**

Aid students in developing advanced content knowledge in chemical engineering and other areas related to their research

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 2 (Expectations):** All students must demonstrate proficiency in graduate level transport phenomena (including fluid dynamics), chemical thermodynamics, kinetics, and applied and computational mathematics. PHD students, in addition, must show proficiency in advanced methods related to these topics. Indicators of content knowledge gains are reflected by consistent progress towards completion of required courses as shown in the programs of study as well as high grades in those courses.

## **Student Learning Outcome 3: Awareness of Ethical Behaviors in the Profession**

### **Define Goal:**

Increase students' awareness of ethical behaviors and communications in the profession

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 3 (Expectations):** All students must show knowledge and applied proficiency of ethics in research approaches. A focused course (CHE 6920) is offered each year to help students with these aspects, and it includes research ethics, research methods, and professionalism in scholarly activities in addition to preparing students for proposal writing and presentations. Further, input and guidance from thesis committee members to students in class and research settings provide additional points for ensuring ethical behaviors.

## **Student Learning Outcome 4: Increased Familiarity with Disciplinary and Interdisciplinary Research Areas in CHE**

### **Define Goal:**

Provide students with broad exposure to various areas of research in the chemical engineering discipline

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 4 (Expectations):** All students must show knowledge of current and relevant areas of research (or other forms of inquiry for the non-thesis option) and must demonstrate a commitment to the process of life-long learning. The Department offers a “Research Seminars Series” to broaden the student exposure about current topics of relevance for the profession. This seminar series is conducted each semester. In addition, though the Chair of the student's thesis (or non-thesis) committee must be a graduate faculty in CHE at TTU, many graduate students have other thesis committee members who are from outside the department and in many cases outside of the College of Engineering. For students pursuing the thesis option, “Certificates of Approval” which are required to be signed by the student's committee and included in the record for each student's thesis reflect this composition. Further, for students pursuing the non-thesis option, a binder containing content (both their original work and resources leveraged) must be submitted by the student for review and approval.

### **Student Learning Outcome 5: Development of Research-Focused Written Communication Skills**

#### **Define Goal:**

Develop competence in science and engineering-based, peer-reviewed, written communication skills

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 5 (Expectations):** All MS thesis students are challenged (desired) to have submitted, at the time of thesis defense, at least one article based on his/her thesis project to a peer-reviewed journal. PHD students are challenged (desired) to have submitted at least three articles. Graduate students also often author or co-author abstracts and conference proceedings. Further, MS (thesis) and PhD students are required to submit an approved thesis (or dissertation for doctoral students) that is approved by their thesis/dissertation advisory committees and the College of Graduate Studies. Non-thesis MS students submit a binder containing original material including (for example) written work, computer codes, presentation materials, etc.

## **Student Learning Outcome 6: Development of Research Presentation and Networking Skills**

### **Define Goal:**

Assist students in developing research presentation skills and in networking to enhance exposure of research findings

### **Intended Outcomes / Objectives:**

**Student Learning Outcome 6 (Expectations):** All students are expected to present in international/national scientific meetings and the university's Student Research and Creative Inquiry Day, and each advisor is to act as a mentor in this effort. As part of research group meetings (and in graduate level courses such as the graduate seminar course CHE 6920), students often present findings from their research and/or from journal articles in the field.

## **Assessment: CHE Department Graduate Student Admissions and Success Database**

### **Goal/ Outcome/ Objective:**

Program Goals 1 (Sufficient Enrollment), 2 (Diverse Students), and 6 (Time to Graduation); Student Learning Outcomes 5 (Writing Skills) and 6 (Presentation Skills)

### **Type of Tool:**

Tracking Spreadsheet, Other

### **Frequency of Assessment:**

Data entered upon entrance of student into program and then periodically throughout the year

### **Rationale:**

These databases are maintained in Excel spreadsheets that are located on a shared drive accessible by the Graduate Program Coordinator and CHE office staff. These spreadsheets include a collection of applicant data (e.g., GRE Scores, BS GPA, TOEFL scores, BS Institution, etc.) for all students applying for admission to the program as well as decisions made by the CHE graduate committee. Upon admission and entry to the graduate program, a separate spreadsheet is used to track each student's entry time, projected graduation date, research advisor, funding status, completion of required courses, and other measures of student success. Data are entered upon entrance of a student into the program and periodically updated.

## **Assessment: Chemical Engineering Graduate Research Association (CEGRA)**

### **Goal/ Outcome/ Objective:**

Program Goal 4 (Meaningful Environment); Student Learning Outcomes 3 (Ethical Behaviors), 4 (Research Depth), and 6 (Presentation Skills)

### **Type of Tool:**

Other

### **Frequency of Assessment:**

Periodically throughout the year during department meetings

### **Rationale:**

The Chemical Engineering Graduate Research Association (generally referred to as CEGRA) is an organization led by CHE graduate students to provide a social and support network for graduate students in the CHE graduate programs. The organization has been in existence since 2003 with a constitution that is periodically reviewed by the membership. Monitoring of activities and updates from the CEGRA Faculty Advisor during departmental meetings and via discussions between the Faculty Advisor, CHE Department Chair and/or Graduate Program Coordinator occur periodically.

## **Assessment: Diversity of Program Demographics**

### **Goal/ Outcome/ Objective:**

Program Goal 2 (Diverse Students); Student Learning Outcomes 4 (Research Depth) and 6 (Presentation Skills)

### **Type of Tool:**

FTE Enrollment, Tracking Spreadsheet, Other

### **Frequency of Assessment:**

Periodically throughout each year

### **Rationale:**

The diversity and student body demographics are routinely examined with this information being maintained in the Student Success Database referenced earlier.

## **Assessment: External and Internal Funding Generated/Obtained**

### **Goal/ Outcome/ Objective:**

Program Goals 1 (Sufficient Enrollment), 5 (Publications/Presentations), and 6 (Time to Graduation)

### **Type of Tool:**

Tracking Spreadsheet,Other

### **Frequency of Assessment:**

Annually

### **Rationale:**

Reports are periodically requested from the TTU Office of Research to provide details on external funding to faculty in the department. In addition, the department maintains a summary of funding status of graduate students in the program and frequently re-assesses this information in efforts to ensure that as many graduate students as possible are supported.

## **Assessment: Graduate Student Enrollment Data**

### **Goal/ Outcome/ Objective:**

Program Goals 1 (Sufficient Enrollment) and 2 (Diverse Students)

### **Type of Tool:**

FTE Enrollment

### **Frequency of Assessment:**

Annually

### **Rationale:**

Graduate student enrollment data is maintained in the Student Success Database, and this information is periodically checked using enrollment data provided via the TTU Office of Institutional Research.

## **Assessment: Periodic Review of Graduate Coursework and Curriculum**

### **Goal/ Outcome/ Objective:**

Program Goals 3 (Rigorous Training) and 6 (Time to Graduation); Student Learning Outcomes 1 (Research Skills), 2 (Content Knowledge), and 3 (Ethical Behaviors)

### **Type of Tool:**

Tracking Spreadsheet,Other

**Frequency of Assessment:**

Periodically, or as the need arises

**Rationale:**

Progress made towards completion of required and elective courses is assessed using a variety of approaches. All graduate students are expected to file a program of study not later than the end of the semester in which they will have earned 15 credits towards their degree, and they are not allowed to register for subsequent semesters if this is not done. Additionally, a review of graduate courses and the curriculum is periodically completed through meetings between the Department Chair and the Research and Graduate Program Coordinator to ensure that courses are offered in a time frame consistent with the program goal for time to graduation. Faculty advisors meet routinely with their advisees to discuss progress in courses and plans for follow-up courses. The Research and Graduate Program Coordinator meets with all new students in the program to discuss courses, the program, and other critical matters. Additions, deletions, and/or changes to the graduate curriculum are first approved via the CHE Graduate Committee and subsequently via the College of Engineering's Graduate Executive Committee (of which the CHE Research and Graduate Program Coordinator is a member), and then the Graduate School Executive Committee (of which the CHE Department Chair is a member).

**Assessment: Thesis Presentation and Defense, Publications, and Other Presentations****Goal/ Outcome/ Objective:**

Program Goal 3 (Rigorous Training); Student Learning Outcomes 1 (Research Skills), 5 (Writing Skills), and 6 (Presentation Skills)

**Type of Tool:**

Other, Dissertation Criteria

**Frequency of Assessment:**

Thesis-related research and presentation are assessed for each MS student pursuing the thesis option at the end of the student's program. Other outcomes such as presentations at Student Research Day are typically assessed annually.

**Rationale:**

All students in the thesis-based MS program are required to complete a thesis presentation and defense. The presentation is completed in a public, seminar-type format at the end of the students' program with the student's thesis committee and others in attendance. Upon completion of the presentation, a question/answer session ensues, and then, with the audience dismissed, the committee discusses the presentation and defense and the student's overall performance in the program and decides whether the student has "passed." As the comprehensive exam is integrated with the thesis defense for MS students, questions may also be asked regarding coursework

completed and student knowledge in his/her area. A non-thesis MS degree is an options for students who desire a more course-work-intensive graduate degree and for students who are directly admitted to the PHD program. An end-of-project presentation is also conducted by students pursuing the non-thesis option. During their programs, students are encouraged and provided the opportunity to be involved in development of manuscripts for submission for peer-reviewed conference proceedings and journal articles and to present at the conferences and the on-campus Student Research Day event.

## **Process of Data Analysis (Assessments/Instruments)**

### **Goal/ Outcome/ Objective:**

This section provides a rationale for the utilization of particular assessment tools and data sources.

### **Type of Tool:**

Other

### **Frequency of Assessment:**

Annually and periodically throughout the year

### **Rationale:**

Information obtained during the assessments is used to ensure that program and student learning outcomes are being met. The databases are maintained by the Research and Graduate Program Coordinator and the CHE office staff. Each faculty in the department monitors his/her advisees' progress and makes adjustments to help ensure that students are progressing satisfactorily towards completing their degree requirements. Program needs and indicators of student quality are routinely assessed and used to guide the process for admission. The CHE Graduate Committee meets periodically to discuss programmatic items, to share ideas for new initiatives, and to conduct initial reviews and make recommendations regarding admission of applicants to the CHE graduate programs. In reviewing applications, the committee uses an 11-item rubric to score applicants (per guidance in the TTU Graduate Catalog). Each applicable item in the rubric is scored out of 10 points, and an overall percentage score is calculated. A threshold score has been established by the committee at or above which an applicant would be recommended for full admission, and a lower score has been established that would lead to a recommendation of provisional admission. Below this latter score, the committee would recommend that admission be denied.

Specific examples of continuous improvement as a result of evaluation of program and student learning outcomes include the following actions: (1) Using input gathered at department and graduate committee meetings, the threshold scores for recommendations of full and provisional admission have been increased steadily over time, with the thought being that those with higher scores will have more potential to be successful in the graduate program. (2) The CHE graduate program has a high percentage of female students and international students as well as of students who are graduates from the CHE undergraduate program. Review of the program demographics continues to be conducted to ensure that these indicators of program diversity are achieved. (3) To

complement on-campus sources of graduate student support and to further increase the amount of external funding, the department Chair as PI and other faculty in CHE and across campus resubmitted (February 2020) a grant proposal to the NSF's National Research Traineeship (NRT) program. (4) Finally, evaluations of the graduate curriculum have resulted in new courses as well as updates to the BS-MS fast-track program and approval of the MS non-thesis CHE option.

Additional information regarding the various assessment instruments are provided below:

**CHE Department Graduate Student Admissions and Success Database** -- A direct assessment of program academic quality by the maintenance of appropriate admissions standards and that these standards are being consistently and uniformly applied. This database is also used to track a number of metrics regarding graduate student success.

**CEGRA** -- In 2003, the CHE graduate student body created the Chemical Engineering Graduate Research Association (CEGRA). This student run organization cares for the needs of the CHE graduate students, organizes events and provides feedback to the CHE faculty concerning the graduate program. CEGRA helps to coordinate the students travel to conferences and provides a variety of other types of support for graduate students in the program.

**Diversity of Program Demographics** -- A measure of the potential for students to obtain/enhance their awareness of global and social issues.

**External and Internal Funding Generated/Obtained** -- The level of external funding provides one indicator of the relevance of research to society at large. It also is an important measure of the extent of faculty engagement in externally funded research projects and a source of support for graduate students. Internal funding (obtained through competitive means such as Faculty Research Grants and other internal granting mechanisms) are important for a variety of purposes including travel support, research support, and classroom improvement initiatives.

**Graduate Student Enrollment Data -- Office of Institutional Research** -- A direct measure of sufficient enrollment in the program to maintain a critical mass of students.

**Periodic Review of Graduate Coursework and Curriculum** -- A periodic review of graduate course offerings and curriculum in order to ensure that the curriculum is both current and relevant to today's continuously evolving and highly technological society.

**Thesis Presentation and Defense, Publications, and Other Presentations** -- The thesis presentation/defense provide a direct measure by the student's Graduate Advisory Committee of the student's ability to conduct research and/ or engage in independent study, demonstrate an enhanced expertise in the student's area of specialization, and showcase proficiency in written and oral technical communication. Other opportunities for demonstration of written and oral communication skills are also provided. The non-thesis project presentation likewise provides an opportunity to assess student's ability to present findings from their projects and their knowledge in the discipline.

## **Results Associated with Program Goal 4 (Meaningful Environment); Student Learning Outcomes 3 (Ethical Behaviors), 4 (Research Depth), and 6 (Presentation Skills)**

### **Results:**

**CEGRA:** During the 2019-20 year, CEGRA had the following activities:

- o- Facilitated attainment of funding for nine graduate students to attend three conferences
- o- Conducted monthly meetings and organized three social outings to promote graduate student interaction and discuss ongoing research
- o- Helped with seminars
- o- Hosted a CEGRA Potluck dinner to promote communication between chemical engineering faculty, graduate students, and undergraduate students
- o- Used social media pages to make announcements and do "Spotlights" on members and their research

These activities help to create a culture for growing professional and other ethical behaviors and provide opportunities for students to see the breadth and depth of knowledge associated with the discipline through their participation in conferences and increased familiarity with other researchers' works.

**External and Internal Funding Generated/Obtained:** The central core of the Graduate Degree Program (MS thesis and PhD dissertation options) in the Department of Chemical Engineering at TTU is learning how to become a *professional researcher*. At the heart of this focus are the research areas and their relevance to the current problems faced by society and the profession. Students, in addition, systematically acquire knowledge by taking fundamental and elective courses to expand their knowledge of advanced chemical engineering concepts and support the successful driving of their research. The current research focus areas in the department are as follows: Electric Field-based Processes, Nanoscale-based Engineered Materials and Systems, Biological-based Processes and Systems, Computational Mathematics and Modeling, and Engineering Education.

A summary of external funds generated (through June 2018) by the CHE department faculty and CHE Center faculty (with tenure in CHE) using data provided by the TTU Office of Research is shown in the table below. While it is recognized that many externally and internally supported projects are interdisciplinary in nature, these activations reflect ones in which the Principal Investigator is a Faculty member in the CHE Department, a reporting approach based on typical TTU Office of Research practices. The general noisy nature of funding is due to (1) movement of the faculty and (2) a small faculty, so fluctuations in any one program greatly affect the whole. Note that this reflects external grant funding only, and occasionally students are funded

externally by their home governments or other means or internally through the TTU Centers of Excellence and other units on campus. During the past few years, faculty in the department have been successful at securing funding via NSF and other funding mechanisms.

<b>Research Activations from Previous 13 Years for the CHE Faculty</b>			
Fiscal Year	CHE/Department Faculty	CHE/Center Faculty	Total
2007-08	\$124,730.00		\$124,730.00
2008-09	\$834,952.00	\$283,718.00	\$1,118,670.00
2009-10	\$366,860.00		\$366,860.00
2010-11	\$129,404.00	\$165,331.00	\$294,735.00
2011-12	\$105,243.00	\$266,561.00	\$371,804.00
2012-13		\$181,597.00	\$181,597.00
2013-14	\$381,057.00	\$176,097.00	\$557,154.00
2014-15	\$298,063.00	\$217,642.00	\$515,705.00
2015-16	\$329,147.00		\$329,147.00
2016-17	\$268,177.00		\$268,177.00
2017-18	\$194,528.00		\$194,528.00
2018-19	\$253,930.00		\$253,930.00
2019-20	\$54,000.00		\$54,000.00

These funds help to enhance the environment for research within the department, provide for increased research depth, and directly or indirectly support graduate students' research projects that lead to theses, dissertations, publications, and presentations.

**Results Associated with Program Goals 1 (Sufficient Enrollment), 2 (Diverse Students), and 6 (Time to Graduation); Student Learning Outcomes 5 (Writing Skills) and 6 (Presentation Skills)**

**Results:**

**Graduate Student Enrollment Data:** The TTU Office of Institutional Research compiles detailed records of all students on campus. From these records, two categories of data regarding the CHE Master’s program are summarized in the first table below for each of the last 17 years. These categories include: 1) the number of students graduating with an MS degree in CHE for each year since 2004 and 2) the number of students enrolled each year in either the CHE Master’s program or those pursuing a doctoral degree with a specialization in CHE in the interdisciplinary College of Engineering PHD program.

Number of CHE-MS Graduates and Graduate Student Enrollment in CHE																		
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Graduates *	MS	10	11	5	4	4	6	4	3	4	2	4	4	6	6	7	4	9
Enrollment ^	MS	16	10	17	18	12	11	8	5	8	12	16	16	16	16	14	13	#
	PHD	3	6	9	8	11	10	11	11	12	14	18	17	17	17	18	15	#
	Total	19	16	26	26	23	21	19	16	20	26	34	33	33	33	32	28	#

\*Graduation data represent the sum of graduates from the Summer-Fall-Spring cycle prior to the Fall in the indicated years. ^Enrollment numbers are based on Fall census data for the indicated years, except for 2012-2019 PHD enrollments which are counted based on known students. Several new MS (and PHD) students were recommended for admission for the Fall 2020 semester. #These values will be added once official numbers are available.

A comparison of enrollment trends for all the BS-CHE, MS-CHE, and PHD-Engineering (with CHE specialization) programs is presented in Figure 1 (Note that bars are not included for 2020 as the official enrollment numbers are still being confirmed.). The department experienced tremendous growth in its BS enrollment (through 2015) and also (through 2014) in the number of students pursuing a PHD in engineering with a specialization in chemical engineering. Since then, these numbers have reduced somewhat for the BS program but held steady for the PHD program. During the time frame from 2002-2011, the enrollment in the MS-CHE program generally declined (Note: MS-CHE program enrollment was 20 and 18 for Fall 2002 and Fall 2003, respectively.) though enrollment spiked in 2006 and 2007. Since 2011, the MS-CHE program enrollment consistently increased from a low of 5 in Fall 2011 to a Fall 2014 enrollment of 16 MS students. Enrollment since then through Fall 2019 (with only a slight reduction in 2018 that held steady for 2019) has been somewhat consistent even as numerous MS students have graduated from the program during this time. The increase in PHD (CHE) enrollments which was 0 in Fall 2002 is largely the direct result of a committed effort within the department to focus on the PHD program in order to increase the research stature of the program and more recently with the addition of new faculty to the program. The increase in the undergraduate enrollment was correlated with the launch in (2007) of a new concentration in biomolecular engineering within the BS-CHE program and in increases in international student enrollment. Such latter enrollments have declined over the last few years which partially explains the reduced BS enrollment. The increase in the MS-CHE enrollment that occurred during this time frame may perhaps be associated with this new biomolecular engineering concentration, new MS admission criteria that no longer require TTU STEM graduates to take the GRE, and also other opportunities, such as novel courses, to ease the transition of non-CHE BS graduates into the MS-CHE program.

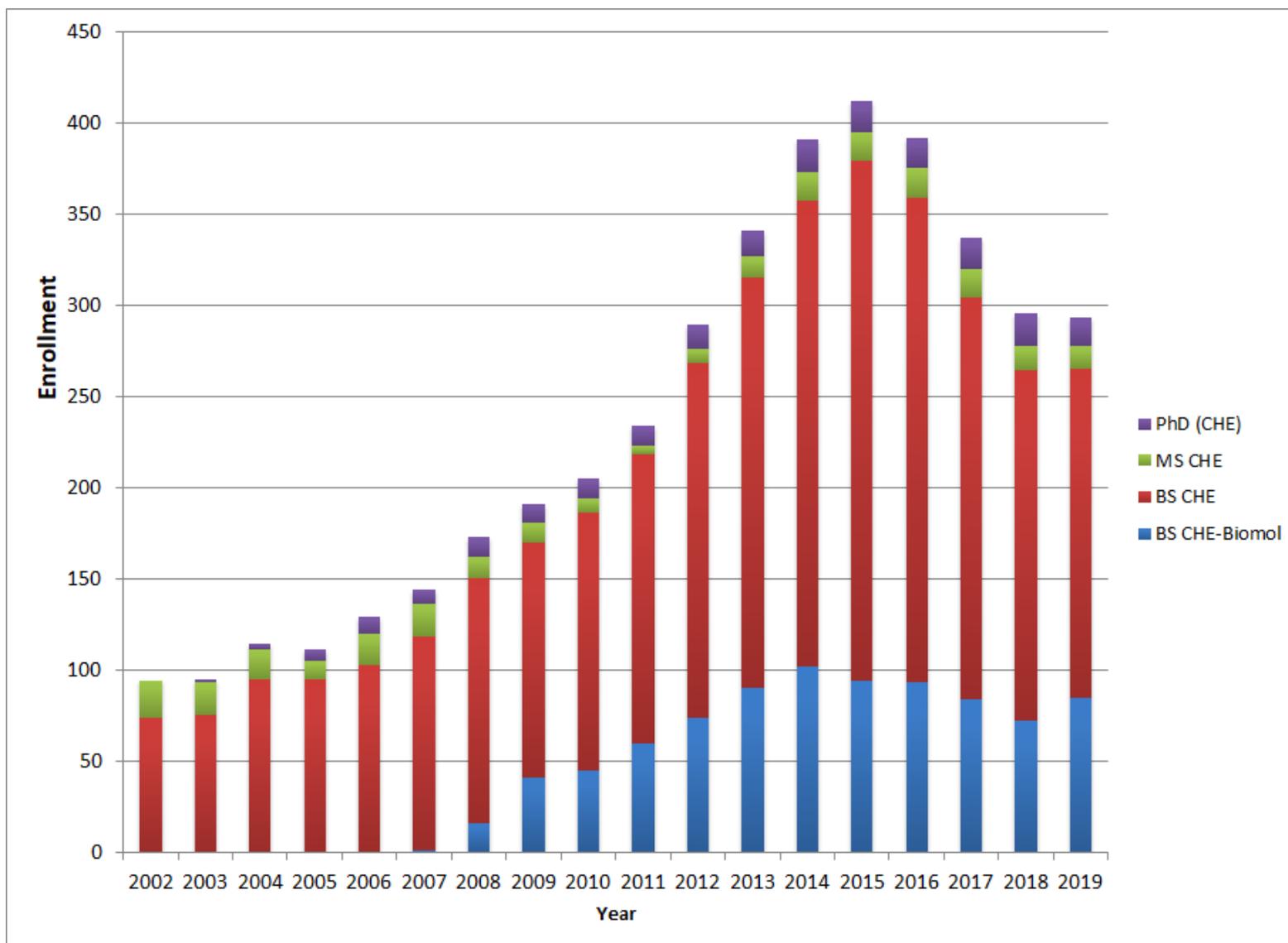


Figure 1: Enrollment trends in the CHE undergraduate and graduate programs. Enrollment for Fall 2020 will be confirmed in September 2020.

In 2014, the MS-CHE program was identified as low producing by the Tennessee Board of Regents (TBR) because the five year rolling average of the number of students graduating with an MS in chemical engineering had dropped below 5.0. Ultimately, the failure to attain benchmarks regarding the number of MS graduates was tied to three major issues: 1) the rapid and substantial growth in the undergraduate program; 2) the departure of several research active faculty prior to 2011; and 3) the fact that the department chose to focus on the PHD program in an effort to increase the research stature of the program. Several corrective action measures that were focused on the following items were pursued to remedy this: 1) Adding new faculty, TAs and staff; 2) Improving program quality; 3) Increasing efficiencies; and 4) Maximizing resources. By implementing this plan and through careful coordination, the program is no longer low producing. Based on five years of data collected through the end of the Spring 2020 semester, the current five year rolling average for MS graduates is 6.4, up from 5.4 for each of the previous two assessments.

**CHE Department Graduate Student Admissions and Success Database:** The department collects information from all students applying for admission to its graduate programs and records several related items (e.g., GRE Scores, BS QPA, TOEFL scores, etc.) in a spreadsheet database. A separate spreadsheet is maintained in which metrics regarding student success (such as completion of core courses, time to completion, grades, indicators of funding, and other indicators of student progress) are tracked.

- Admission Scores -- New admission criteria were approved in 2014 for the MS programs in the TTU College of Engineering. As such, admission decisions to the MS-CHE program are now based on a comprehensive assessment that includes such factors as whether the student has research experience at the undergraduate level in addition to factors such as GPA, GRE scores, etc.

<Admission requirements are posted in the TTU Graduate Catalog.>

A total of 19 applicants applied to the CHE graduate programs for an entrance term sometime during 2019. Of those, 12 applied for admission to the MS-CHE program, and 7 applied for admission to the PHD program. Four applicants were recommended for full admission to the MS-CHE program. Three applicants were recommended for provisional standing in the MS-CHE program, and another four applicants were denied admission to the MS-CHE program. One application was postponed for evaluation. As indicated in the table below, among the MS-CHE program applicants who submitted GRE scores (Note: TTU STEM graduates do not have to take the GRE.), the average Verbal plus Quantitative (V+Q) score was similar for those admitted in full or provisional standing and lowest for those denied admission. Applicants presented with similar Analytical Writing scores.

	Full Standing			Provisional Standing			Denied		
	V	Q	AW	V	Q	AW	V	Q	AW
2019	153.0	151.8	3.5	147.5	157.0	2.8	144.8	151.3	3.0
	V+Q = 304.8			V+Q = 304.5			V+Q = 296.1		
	n=4			n=2			n=4		

- Time to Completion -- The average amount of time for the nine students graduating in the Summer 2019-Fall 2019-Spring 2020 cycle is as follows:
  - 33.3 months (MS thesis option, n=3), Range: 28-40 months
  - 34.0 months (MS non-thesis option, n=2), Range 32-36 months
  - 42.0 months (MS non-thesis, direct PHD program, n=4), Range: 28-48 months
- Publications -- Many of our MS students are included in publications (sometimes as first author) based on their thesis research, and sometimes this occurs after a student has graduated. All theses are archived and almost always available electronically through the ProQuest Dissertations & Theses database (Occasionally, these might be embargoed for a period of time in cases that additional time is needed to protect intellectual property.)
- Student Presentations -- Students routinely attend conferences and present their research results. They also present research during the Student Research Day event held each spring on the TTU campus. These results are summarized elsewhere in this report.
- Other Indicators -- Student grades are monitored by students, Faculty Advisors, the Research and Graduate Program Coordinator, and the Graduate School. Whether core courses have been completed is monitored by Faculty Advisors and the Research and Graduate Program Coordinator (the latter through the Student Success database). The quality of research and MS student productivity/successes are monitored by Faculty Advisors and Thesis Committee Members, and a variety of methods specific to the Advisors are used. MS students who serve as teaching assistants meet periodically with the instructors of the courses for which they TA. Students who are supported financially through the Centers of Excellence and other units on campus (such as the Office of Research) are generally expected to provide summary reports to document the type and quality of research completed by the students.

**Diversity of program demographics:** The departmental culture is inclusive, and the faculty and staff wholeheartedly seek to include diverse perspectives and experiences throughout curricular and extracurricular activities. Faculty are from the U.S. and international locations including Argentina, China, and India. Five of the ten full-time faculty (tenured or tenure-track or Instructor) in the department are female, and on the order of 30-40% of the CHE undergraduate and graduate program enrollments are female. Many of the graduate students are Tennessee natives, and others are from such countries as Bangladesh, Brazil, China, Hungary, India, Iran, Iraq, Nepal, Nigeria, and Taiwan. Each faculty leads a research group that includes students from various locations, and these groups typically meet often to update each other on research progress, to share insights, and to learn from each other and benefit from the unique perspectives in the group. The faculty hold terminal degrees from various types of institutions including large state universities and smaller private institutions. As indicated earlier in the report, per Fall 2019 census, 43% overall (46% at the MS level) of the graduate students in the program are female graduate students.

**External and Internal Funding Generated/Obtained:** A variety of funding mechanisms are leveraged to help with maintaining a diverse and sufficient enrollment. As an example, one graduate student is currently supported through an NSF Graduate Research Fellowship, and some students are also supported through grants to faculty. Many other students in the department are supported through Research Assistantships from the TTU Centers of Excellence and other units and as Teaching Assistants funding via the Department of Chemical Engineering and the College of Engineering. Additional details regarding funding are provided elsewhere in the report.

## **Results Associated with Program Goals 3 (Rigorous Training), 5 (Publications, Presentations), and 6 (Time to Graduation) and Student Learning Outcomes 1 (Research Skills), 2 (Content Knowledge), and 3 (Ethical Behaviors)**

### **Results:**

**Periodic Review of Graduate Coursework and Curriculum:** A variety of activities are pursued to ensure rigorous training. Aspects of the curriculum are discussed during department and department graduate committee meetings, and the information is used to guide curricular improvement. The content of the curriculum is often adapted, largely through the development of new elective courses that align with faculty areas of expertise and student interest. Additional changes occur as needs and resources in the department allow. Examples of these areas of improvement are provided below. The four core courses in the MS-CHE graduate program focus on development of advanced skills in mathematics, thermodynamics, transport, and kinetics and are given as follows:

- o- MATH 5510: Advanced Math for Engineers
- o- CHE 6010: Advanced Chemical Engineering Thermodynamics
- o- CHE 6140: Physics of Transport or ME 6040: Intermediate Fluid Dynamics
- o- CHE 6210: Advanced Kinetics

The math course is offered each semester (including summers), and the CHE courses are offered annually based on annual review of student needs to ensure appropriate sequencing and availability of courses. On a rare occasion, to maximize alignment with graduate research, a course may be substituted for one of these core CHE courses, upon approval by the student's advisory committee and Department Chair. In addition to the 12 credits provided through the core courses, students also must complete an additional 12 elective credits (four courses) and 6 credits in research/thesis (CHE 6990) for those pursuing a thesis option. As expected, all requirements for the non-thesis option as outlined in the Graduate Catalog must likewise be met. This includes completion of the core courses described above (12 credits) plus an additional 22 course credits (which must include the 1 credit hour graduate seminar course CHE 6920 and a 3-credit project course CHE 6970) for a total of 34 credits.

Four direct admit PhD students completed the project course (CHE 6970) during the current reporting cycle such that they completed the requirements to earn the non-thesis MS along the way to their PhD as allowed by the graduate program. Two additional non-thesis MS students also completed their programs during this reporting period. One of these students transitioned from the direct admit PHD program while the other student transitioned from the MS thesis program. Thus, the non-thesis option provided a viable path for those students to move forward in-line with their career goals.

As the number of faculty in the department has increased and stabilized, the department has been working to increase the number and variety of graduate elective courses which has been a limitation in the program in the past. During the 2019-20 academic year, nine 6000-level graduate

courses (including the required CHE 6010, CHE 6140, and CHE 6210 courses as well as the graduate seminar course CHE 6920) and three 7000-level graduate elective courses were offered in the department. These electives (especially the 7000-level courses) tend to have very small enrollments and are often customized to research group needs as described further below.

Overall, elective course offerings have been developed along two thrusts. First, the department has attempted to offer at least one graduate CHE elective every semester. (Also, students are allowed to take electives from other departments as interest and research needs dictate.) Second, the department has engaged the faculty to pilot and build new state-of-the-art courses and formally process the curricula to appear in the graduate catalog. To achieve this outcome, any faculty simply needs to discuss at a department meeting the desire to make a course “permanent” and to work with the Research and Graduate Program Coordinator and the office staff to complete a memo that is routed from the committee, via the Chair, to the college Graduate Executive Committee, and then to the Graduate Studies Executive Committee for final approval and implementation in the graduate catalog. The CHE 6140: Physics of Transport course (which is now considered a core as indicated above) had been offered three times during the recent past as a special topics course (listed as CHE 6810), and through this process, it was officially established as a permanent course during 2017. Ultimately, through discussions in the department, this course is recognized as a preparatory course for the Advanced Kinetics course and as a critical course for any graduate students who do not have an undergraduate degree in CHE, thus supporting its approval as a core course in the curriculum. With only a few exceptions owing to other student needs, the Research and Graduate Program Coordinator advises new graduate students to take the CHE 6140 course during their first semester in preparation for the Advanced Kinetics course in the subsequent spring semester. Some students also or alternatively complete the Intermediate Fluid Dynamics course if the student’s research is focused in this area of the discipline.

As new electives create additional opportunities to align courses in a way that enhances performance on research projects, complementary approaches are also being pursued. For example, to further increase the research experience for MS students, discussions have ensued regarding the possibility of reducing the number of formal courses and increasing the amount of time dedicated to research. Discussions on this topic continue to occur and represent an important focus area for consideration.

Courses are offered in a sequence and time frame that is compatible with student progression towards meeting degree objectives. To help ensure that this is the case, frequent meetings occur between the Research and Graduate Program Coordinator and the Department Chair. In some of these meetings, the two discuss course needs, which take into account the number of students who might be needing a given class plus the goal that the department offers at least one of the required courses each semester. (Note: As indicated above, MATH 5510 is offered every semester [including summers] by faculty in the Department of Mathematics). Elective courses within and outside the department are also offered at a frequency to ensure that course availability is not an impediment to graduation. Core CHE courses are typically offered once each academic year with a summary provided in the table below.

Schedule of Core Graduate Courses Offered by the CHE Program (Fall 2012 - Spring 2020)																
Core Courses	F'12	Sp'13	F'13	Sp'14	F'14	Sp'15	F'15	Sp'16	F'16	Sp'17	F'17	Sp'18	F'18	Sp'19	F'19	Sp'20
CHE 6010		X				X		X		X		X			X	
CHE/ME 6040*	X		X		X		X		X		X		X			
CHE 6810/6140**	X			X			X				X		X		X	
CHE 6210		X			X		X	X		X		X		X		X

\* Dual-listed as CHE/ME 6040 until Fall 2016 then just ME 6040

\*\* Changed from a special topics course (6810) to a permanent course (6140) effective Fall 2017

With this schedule of course offerings, students have been able to make timely progress towards meeting their degree objectives. Ultimately, the time-to-degree for MS-CHE students has held relatively constant over the years even with the growth in the undergraduate and graduate programs, but assessments for the current reporting period as well as the previous one suggest an overall increase in the time-to-degree for students pursuing an MS degree in CHE.

**Thesis Presentation and Defense:** The rigor of the training is also verified through assessments during the thesis presentation and defense. No significant changes (plus or minus) in student performance have been reported by faculty in regards to the performance of graduate students during their thesis presentation/course study defense. At this time, the student thesis is reviewed and the defense is heard by the thesis committee. If satisfied, the committee then signs a form stating that the student has passed the defense, with minimal notes regarding the student's performance typically written on the reverse side in free form.

**Publications:** Graduate students have opportunities for first author and co-authorship on publications in peer-reviewed journals and conference proceedings. A goal for MS-CHE students is that they have at least one publication or manuscript submitted by the time of graduation, though not meeting this goal does not prevent a student from graduating. Of the nine CHE students earning an MS degree during the 2019-20 fiscal year, at least four of these are author or co-author on a peer-reviewed publication and/or conference proceeding. All theses are copyrighted and archived in the ProQuest Thesis and Dissertation Database.

## Results for Student Learning Outcome 6 (Presentation Skills)

### Results:

**Student Presentations:** In addition to an oral presentation/defense of a thesis as described elsewhere, students routinely attend conferences and present their research results. They also present research during the Student Research and Creative Inquiry Day (Research Day) event held each spring on the TTU campus. During the 2020 Research Day, in addition to 8 CHE undergraduates, 4 CHE MS students presented their research while 10 CHE PHD students presented their research. The number of CHE MS students presenting during this year was similar to the previous year's number of presentations.

CHE Student Research Day Presentations by Degree Objective									
	2012	2013	2014	2015	2016	2017	2018	2019	2020
BS	20	17	14	17	9	16	17	15	8
MS	2	6	6	11	12	13	7	3	4
PhD	16	12	9	12	10	10	13	13	10
Total	38	35	29	40	31	39	37	31	22

All CHE-MS graduates (n=9) during the 2019-2020 cycle (summer-fall-spring) presented their research in a public forum on-campus at the end of their programs. This includes 3 students completing their thesis-based MS program and 6 students completing the non-thesis option (Note: 4 of these 6 students are from the direct-admit PhD program).

## New Modifications and Continuing Improvement to Goals/Objectives/Outcomes Item

### Goal/Objective/Outcome Number:

Program Goals 1-6; Student Learning Outcomes 1-6

### Program Changes and Actions due to Results:

Increasing the amount of funding (especially external funding) to support graduate students in the program tends to be challenging. This is an area that will have an impact on enrollment and the research environment if not adequately addressed. Thus, it is an important area for focus. For each of the last three years, the department has submitted a grant application to the NSF National Research Training (NRT) program that if funded would provide assistantships over a five year period to numerous graduate students from Appalachian, Native American, and other rural communities. The application was not funded in 2020, but plans are underway to resubmit in early 2021. Similar efforts at seeking external funding continue to be pursued by the faculty.

**Link to Assessment:**

As detailed throughout this report, seven primary means/tools of assessment are used within the MS-CHE program to ensure that the program is meeting its goals and that the student learning outcomes are achieved.

**Link to 'Tech Tomorrow' Strategic Plan:**

Diverse Faculty and Staff, Diversity, Technology Infused Programs, Research, Scholar, Intellect, and Creativity, Efficiency and Effectiveness

**New Improvement to Assessment Plan Item****Improvements to Assessment Plan:**

The assessment plan has remained unchanged from the previous year's report though the department continues to improve its methods used in tracking and archiving data.