

Institutional Effectiveness 2020-2021

Program: Chemical Engineering MS

College & Department: College of Engineering – Department of 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.

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 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.

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 Goals:

- PG 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.
- PG 2: Maintain a diverse graduate student body consisting of domestic and foreign students including minorities and individuals of underrepresented groups.
- PG 3: Provide students with a rigorous, interdisciplinary, and current training through both course work and research projects in relevant areas of modern chemical engineering.

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

Student Learning Outcomes:

- SLO 1: All students must demonstrate knowledge and proficiency in the method of scientific inquiry. Development of these skills is demonstrated via numerous means including:
- 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 or, for those pursuing the non-thesis MS degree, satisfactory performance in the CHE 6970 project course;
 - completion of a written thesis (or for the non-thesis MS degree, submission of an organized project binder with synthesized material) with appropriate content and presentation format that is accepted by the student's advisor, the student's committee, and the Dean of the College of Graduate Studies (thesis only);
 - oral presentation and defense of the thesis research (or non-thesis) project in front of the student's advisory committee, student peers, and the general chemical engineering faculty and
 - 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 (or project).
- SLO 2: All students must demonstrate proficiency in graduate level transport phenomena (including fluid dynamics), chemical thermodynamics, kinetics, and applied and computational mathematics. 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.
- SLO 3: 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.
- SLO 4: All students must show knowledge of current and relevant areas of research 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 committee members who are from outside the department and in many cases outside of the College of Engineering. "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.

SLO 5: All MS students are challenged to have submitted, at the time of thesis defense, at least one article based on his/her thesis project to a peer-reviewed journal. Graduate students also often author or co-author abstracts and conference proceedings. Further, MS students are required to submit an approved thesis that is approved by their thesis advisory committees and the College of Graduate Studies.

SLO 6: All students are expected to present in international/national scientific meetings, and each advisor is to act as a mentor in this effort. As part of research group meetings, students often present findings from their research and/or from journal articles in the field.

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

Assessment Methods:

1. *CHE Department Graduate Student Admissions and Success Database:* These databases are maintained in Excel spreadsheets that are located on a shared drive accessible by the Graduate Program Coordinator and CHE office staff. The department is also leveraging Microsoft Teams for sharing and archiving information related to the program. 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.
2. *Chemical Engineering Graduate Research Association (CEGRA):* 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.
3. *Diversity of Program Demographics:* The diversity and student body demographics are routinely examined with this information being maintained in the Student Success Database.
4. *External and Internal Funding Generated/Obtained:* Reports are periodically requested from the TTU Office of Research (or obtained from its website) 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.

5. *Graduate Student Enrollment Data:* 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.
6. *Periodic Review of Graduate Coursework and Curriculum:* 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 generally 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 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 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 Graduate Program Coordinator is a member), and then the Graduate School Executive Committee.
7. *Thesis Presentation and Defense, Publications, and Other Presentations:* 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 also possible for students who desire a more course work intensive graduate degree and for students who are directly admitted to the PHD program. During their program, 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 conferences and the on-campus Student Research and Creative Inquiry Day event.

Process of Data Analysis (Assessments/Instruments)

Information obtained during the assessments is used to ensure that program and student learning outcomes are being met. The databases (and Teams' folders) are maintained by the 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 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). 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 increased steadily over time (but are now somewhat consistent year-in and year-out), with the thought being that those with higher scores will have more potential to be successful in the graduate program. (2) For this reporting period, the CHE graduate program shows a modest percentage of female students, a somewhat high percentage of international students, and several students who are graduates from the CHE undergraduate program. Review of the program demographics continues to be conducted to ensure that 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, faculty in CHE and across campus resubmitted (September 2021) a grant proposal to the NSF's National Research Traineeship (NRT) program that is focused on new assistantships and research opportunities. (4) In 2020-2021 year, the Chair dedicated several faculty meetings to soliciting ideas for improvement, and required every faculty to turn in quad charts, intent to submit forms, and plans for conference travel to be funded by the Department. (5) Finally, as examples, 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.

| | Assessment Process | | Program Goals | Student Learning Outcomes | Assessment Frequency |
|---|--|--------------------------------------|---------------|---------------------------|---|
| 1 | CHE Department Graduate Student Admissions and Success Database | Tracking spreadsheet | 1,2,3 | 5,6 | Upon entrance of student into program and then periodically throughout the year |
| 2 | Chemical Engineering Graduate Research Association (CEGRA) | Other | 4 | 3,4,6 | Periodically throughout the year during department meetings |
| 3 | Diversity of Program Demographics | FTE Enrollment, Tracking spreadsheet | 2 | 4,6 | Periodically throughout each year |
| 4 | External and Internal Funding Generated/Obtained | Tracking spreadsheet | 1,5,6 | | Annually |
| 5 | Graduate Student Enrollment Data | FTE Enrollment | 1,2 | | Annually |
| 6 | Periodic Review of Graduate Coursework and Curriculum | Tracking spreadsheet | 3,6 | 1,2,3 | Periodically, or as the need arises |
| 7 | Thesis Presentation and Defense, Publications, and Other Presentations | Dissertation Criteria | 3 | 1,5,6 | End of the student's program and presentations at Student Research Day |

Results:

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

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 16 years. These categories include: 1) the number of students graduating with an MS degree in CHE for each year since 2006 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 | | | | | | | | | | | | | | | | | |
|---|-------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| Graduates* | MS | 5 | 4 | 4 | 6 | 4 | 3 | 4 | 2 | 4 | 4 | 6 | 6 | 7 | 4 | 9 | 3 |
| | | | | | | | | | | | | | | | | | |
| Enrollment^ | MS | 17 | 18 | 12 | 11 | 8 | 5 | 8 | 12 | 16 | 16 | 16 | 16 | 14 | 13 | 12 | # |
| | PHD | 9 | 8 | 11 | 10 | 11 | 11 | 12 | 14 | 18 | 17 | 17 | 17 | 18 | 15 | 13 | # |
| | Total | 26 | 26 | 23 | 21 | 19 | 16 | 20 | 26 | 34 | 33 | 33 | 33 | 32 | 28 | 25 | # |

* 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 2012-2020 PHD enrollments which are counted based on known students. Several new MS (and PHD) students were recommended for admission for the Fall 2021 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 2021 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 (and over the last few years or so), these numbers have reduced considerably for the BS program and are down 20-25% for the MS and PHD programs since 2017. 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. Subsequently, 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 from then held steady at 16 through Fall 2017, even as numerous MS students graduated from the program during that 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 the biomolecular engineering concentration that launched in 2007, 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. The more recent reductions in the MS-CHE and PHD-Engineering (with CHE specialization) programs point to the need for additional focused efforts.

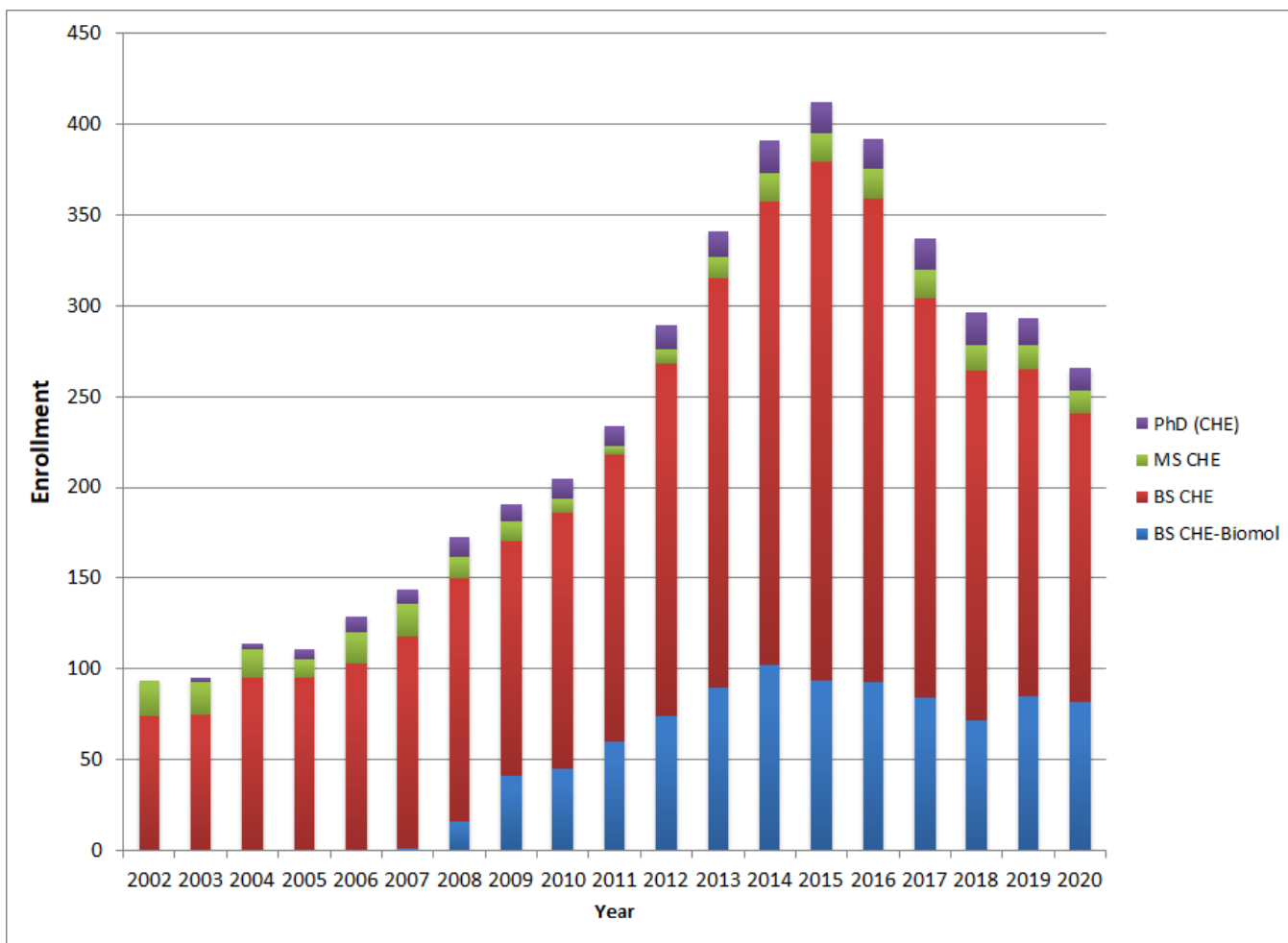


Figure 1: Enrollment trends in the CHE undergraduate and graduate programs. Enrollment for Fall 2021 will be confirmed in September 2021.

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 2021 semester, the current five-year rolling average for MS graduates is 5.8, down from the previous assessment of 6.4. The two assessments prior to last year showed the five-year rolling average at 5.4. Projecting forward, the department will need two MS graduates during the current cycle to maintain an average of 5.0 and will need to graduate seven (or fewer if this year's number is more than two) MS-CHE students during the following cycle. As mentioned above, we have added an MS (non-thesis) degree opportunity "along the way" to the PHD. We have also added advertisement of classes across the College of Engineering every semester and have also added a new program, on ramp, approved University-wide in May 2021, whereby employees or distance learners with an appropriate BS can take graduate classes without a program of study, up to 15 hours.

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.>

During the 2020-21 reporting period, with consideration of the impact of the COVID pandemic on those seeking admission to graduate programs, GRE scores were not required by the TTU Graduate School. Thus, these data are sparsely available. A more detailed analysis of applicant metrics and admission decisions for the 2020 calendar year will be completed.

- Time to Completion -- The average amount of time for the three MS-CHE students graduating in the Summer 2020-Fall 2020-Spring 2021 cycle is as follows:
 - 33.0 months (MS thesis option, n=2), Range: Both graduates completed their program at ~33 months.
 - N/A months (MS non-thesis option, n=0), Range: N/A
 - 40.0 months (MS non-thesis, direct PHD program, n=1), Range: 40 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 and Creative Inquiry 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 Graduate Program Coordinator, and the Graduate School. Whether core courses have been completed is monitored by Faculty Advisors and the 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) (see details below) 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 during this reporting period 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 typically on the order of 25-40% of the CHE undergraduate and graduate program enrollments are female. Many of the graduate students are Tennessee natives, and other current students are from such countries as Brazil, 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 2020 census, 28% overall (33% 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. Some students are supported through faculty grants. Many other students in the department are supported on Research Assistantships via "Carnegie Funding" through the TTU College of Engineering with other internal funding sources including the Centers of Excellence, the Office of Research, and other units. Several students are supported each year as Teaching Assistants funded through the Department of Chemical Engineering and the College of Engineering. Additional details regarding research funding are provided elsewhere in the report, and efforts focused on increasing funding from external sources are being pursued.

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)

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:

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

The math course is offered each semester (including summers), and the CHE courses are offered (almost always) 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.

One direct-admit PhD student completed the project course (CHE 6970) during the current reporting cycle such that the student completed the requirements to earn the non-thesis MS along the way to the PhD as allowed by the graduate program. Since August 2019, five direct admit PhD students and two direct non-thesis students have completed the MS-CHE degree. Thus, the non-thesis option has provided a viable path for those students to move forward in-line with their career goals.

As the number of faculty in the department stabilized over the last few years, the department has worked to increase the number and variety of graduate elective courses which had been a limitation in the program in the past. During the 2020-21 academic year, eight 6000-level graduate courses (including the required CHE 6010 and CHE 6140 courses as well as the graduate seminar course CHE 6920) and two 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.

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 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) 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 Graduate Program Coordinator advises new graduate students entering in the fall semester to take the CHE 6140 course during their first semester (if it is offered) 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 occurred in the past regarding the possibility of reducing the number of formal courses and increasing the amount of time dedicated to research. Discussions on this topic have stalled though still represent a 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, communications occur between the Graduate Program Coordinator and the Department Chair. In some of these, the two discuss course needs, which take into account the number of students who might be needing a given class. (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 (Note: On a rare occasion, it is possible that one of the core CHE courses does not need to be offered during a semester.).

| Schedule of Core Graduate Courses Offered by the CHE Program (Fall 2013 - Spring 2021) | | | | | | | | | | | | | | | | |
|---|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|-------------|--------------|
| Core Courses | 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 | F'20 | Sp'21 |
| 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 | | |

* 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 two periods suggest an overall higher (but now flattening) time-to-degree for students pursuing an MS degree in CHE. Specifically, for the MS-thesis based program, the two graduates each took ~33 months to complete the degree.

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 regard 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. The CHE office also has begun to maintain a rubric score sheet gathered from all attendees during the MS defense. This scoring sheet was developed and approved at a 2021 faculty meeting, and assessments based on the scoring sheet will be tracked in future reports.

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 three CHE students earning an MS degree (two thesis-based and one non-thesis-based) during the 2020-21 fiscal year, one of these was a co-author on three peer-reviewed publications while all three are authors/co-authors on abstracts and corresponding works that were presented at conferences. All of these are copyrighted and archived in the ProQuest Thesis and Dissertation Database.

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

CEGRA: During the 2020-21 year, CEGRA had the following activities:

- Facilitated attainment of funding for nine graduate students to attend four conferences
- Conducted monthly meetings and organized one social outing to promote graduate student interaction and discuss ongoing research
- Helped with seminars
- Hosted a CEGRA Potluck dinner (at the department chair's home) to promote communication between chemical engineering faculty, graduate students, and undergraduate students; 12 NSF REU undergraduates were also hosted.
- 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 2021) 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.

| Research Activations from Previous 13 Years for the CHE Faculty | | | |
|--|-------------------------------|----------------------------|----------------|
| 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 |
| 2020-21 | \$192,605.00 | | \$192,605.00 |

* The reporting structure was changed recently such that all CHE faculty now have their primary appointment in the department.

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.

Student Learning Outcome 6 (Presentation Skills)

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 2021 Research Day (held virtually), in addition to 13 CHE undergraduates, 5 CHE MS students presented their research while 9 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 | 2021 |
| BS | 20 | 17 | 14 | 17 | 9 | 16 | 17 | 15 | 8 | 13 |
| MS | 2 | 6 | 6 | 11 | 12 | 13 | 7 | 3 | 4 | 5 |
| PhD | 16 | 12 | 9 | 12 | 10 | 10 | 13 | 13 | 10 | 9 |
| Total | 38 | 35 | 29 | 40 | 31 | 39 | 37 | 31 | 22 | 27 |

All CHE-MS graduates (n=3) during the 2020-2021 cycle (summer-fall-spring) presented their research in a public forum on-line or on-campus at the end of their programs. This included 2 students who completed their thesis-based MS program and 1 student who completed the non-thesis option as part of the direct-admit PhD program.

Modifications for Improvement

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 was resubmitted in September 2021. Similar efforts at seeking external funding continue to be pursued by the faculty.

Effective for a few months now and aligned with expectations throughout the College of Engineering, the department now requests that the audience in attendance at MS thesis and PHD dissertation defenses evaluate the candidates using a new form. This assessment will be incorporated in next year's report.

Appendices

1. Curriculum Map – Thesis Option
2. Curriculum Map – Non-Thesis Option

Appendix 1: Curriculum Map – Thesis Option

Chemical Engineering, MS (Thesis): Mapping of the Graduate Curriculum and Student Learning Objectives

| Course | Title | Student Outcomes | | | | | |
|--|--|--------------------------|----------------------------|----------------------------|-------------------------|-------------------------|------------------------------|
| | | SLO1: Research Skills | SLO2: Content Knowledge | SLO3: Ethical Behaviors | SLO4: Research Depth | SLO5: Writing Skills | SLO6: Presentation Skills |
| CHE 6010 | Advanced Chemical Engineering Thermodynamics | | X | X | | | |
| ME 6040 OR CHE 6140 | Intermediate Fluids or Physics of Transport | | X | X | | | |
| CHE 6210 | Advanced Kinetics | | X | X | | | |
| MATH 5510 | Advanced Math for Engineers | | X | X | | | |
| 5000, 6000, or 7000-level elective | Four, 3-credit courses selected from any TTU STEM graduate course deemed appropriate by students' advisory committee with a maximum of 9 credits total at the 5000-level including MATH 5510 | | X | | X | | |
| CHE 6920* | Graduate Seminar | X | | X | X | | X |
| CHE 6990 | Research and Thesis (6 credits total) | X | | X | X | X | X |
| | | | | | | | |
| *Optional, though often taken | | | | | | | |
| X Organically happens that interactions lead to conversations in these classes on plagiarism, etc. | | | | | | | |
| Many CHE graduate students also actively participate as members of the Chemical Engineering Graduate Research Association (CEGRA) that provides academic, research, and social support to members. | | | | | | | |

Appendix 2: Curriculum Map – Non-Thesis Option

Chemical Engineering, MS (Non-Thesis): Mapping of the Graduate Curriculum and Student Learning Objectives

| Course | Title | Student Outcomes | | | | | |
|--|---|--------------------------|----------------------------|----------------------------|-------------------------|-------------------------|------------------------------|
| | | SLO1: Research Skills | SLO2: Content Knowledge | SLO3: Ethical Behaviors | SLO4: Research Depth | SLO5: Writing Skills | SLO6: Presentation Skills |
| CHE 6010 | Advanced Chemical Engineering Thermodynamics | | X | X | | | |
| ME 6040 OR CHE 6140 | Intermediate Fluids or Physics of Transport | | X | X | | | |
| CHE 6210 | Advanced Kinetics | | X | X | | | |
| MATH 5510 | Advanced Math for Engineers | | X | X | | | |
| 5000, 6000, or 7000-level elective | Six, 3-credit courses selected from any TTU STEM graduate course deemed appropriate by students' advisory committee with a maximum of 9 credits total at the 5000-level including MATH 5510 | | X | | X | | |
| CHE 6920 | Graduate Seminar | X | | X | X | | X |
| CHE 6970 | Project | | X | X | X | X | X |
| | | | | | | | |
| | | | | | | | |
| X Organically happens that interactions lead to conversations in these classes on plagiarism, etc. | | | | | | | |
| Many CHE graduate students also actively participate as members of the Chemical Engineering Graduate Research Association (CEGRA) that provides academic, research, and social support to members. | | | | | | | |