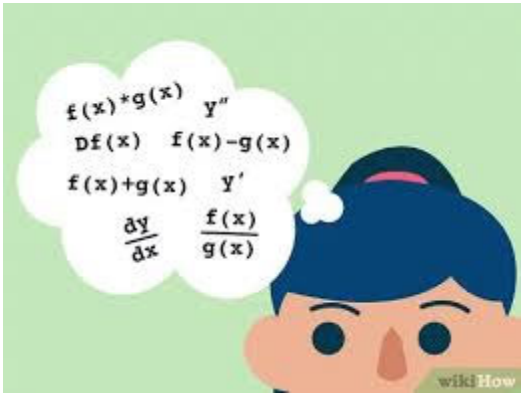
Improving Students' Skills in Calculus-Based Thermodynamic Applications and Research Publications

Chemistry M.S. Program

By Sujata Guha, Professor of Chemistry, Tennessee State University



The Department of Chemistry at Tennessee State University offers the Master of Science (M.S.) degree in Chemistry with concentrations in Professional Chemistry and Biochemistry. The objectives of the M.S. program include advancing, interpreting, disseminating, and preserving knowledge of chemistry; engaging students in research and publication of new scientific knowledge; and training graduate students to take their proper place in industry, education, and public life. The faculty in the Chemistry M.S. Program have regularly assessed student learning outcomes using quantitative data, such as performance in exams and homework assignments, along with course grades. The faculty's choice to improve student learning coincided with the university-wide continuous improvement efforts and to maintain the educational programs accreditation standards for student learning outcomes, in collaboration with the Office of Institutional Effectiveness, Research, Planning, and Assessment. Three student learning outcomes (SLOs) were developed along with measurement tools and the criteria for success, based on a 1-5 points scoring rubric, as follows: 1 (Unsatisfactory); 2 (Developing); 3 (Satisfactory); 4 (Competent); and 5 (Accomplished). SLO-1 stated that "Students will present and defend an original scientific research project with the purpose of generating new knowledge in either the

Professional Chemistry Concentration or the Biochemistry Concentration;" SLO-2 stated that "Students will be able to apply the concepts of calculus to determine enthalpy changes for thermodynamic systems for the Professional Chemistry Concentration;" while SLO-3 stated that "Students will be able to apply the basic principles of biochemical instrumentation in determining the purity, stability, size, conformation and binding characteristics of biomolecules found in living organisms for the Biochemistry Concentration." To demonstrate achievement of these outcomes, students would need to achieve a minimum score of 3 points or higher on the scoring rubric for each of the measurement tools for each SLO. The criteria for success (benchmark/performance target) for AY 2017-2018 was for 75% of the students to meet the standards for each SLO. The benchmark was increased to 80% for AY 2018-2019, and 85% for AY 2019-2020. Student performances related to each SLO were scored using the rubric and the results were analyzed. Based upon the analysis, improvements were suggested related to each SLO, to be incorporated during the following academic year.

SLO-1 was measured by two tools: (1) Application of correct methodology to solve the research problem; and (2) Successful thesis defense in front of committee members, faculty, and students. Analysis of student performances indicated that all students (100%) met or exceeded the benchmark during AY 2017-2018 (5 out of 5 students), 2018-2019 (5 out of 5 students), and 2019-2020 (6 out of 6 students), as determined by the rubric. Even so, to further strengthen the program, improvement measures were suggested, such as asking the students to give a brief overview of their research results to the graduate program coordinator, encouraging faculty to submit grant proposals to external funding agencies to strengthen their research infrastructure, and inviting doctoral students from other departments with research interests in chemistry to conduct collaborative research with a chemistry faculty member. Students were provided an overview of research protocols during departmental graduate student orientation at the beginning of the academic year, and encouraged to attend at least one professional research conference each year. Research advisors were asked to have their students give research overviews/presentations each month during their group meetings.

SLO-2 related directly to an area in which some of the graduate students have traditionally struggled, such as demonstrating appropriate-level proficiency in the applications of single and multivariable calculus to thermodynamics. Two measurement tools were developed for that SLO: (1) Analysis of answers to enthalpy-related calculations in Advanced Physical Chemistry I (CHEM 5310), a required course for the Professional Chemistry Concentration; and (2) Analysis of

enthalpy-related derivations in CHEM 5310. The student's answers to conceptual and computational questions related to enthalpy would demonstrate their understanding of heat flow and changes related to thermodynamic systems. Analysis of student performance for AY 2017-2018 indicated that 2 out of 3 total students (66.7%) exceeded the performance target in each measurement tool for SLO-2. 2 students scored 4 points for each measurement tool (indicating above benchmark), while 1 student scored 2 points on each measurement tool (indicating below benchmark). The results showed that, for the 1 student to have met the benchmark, improvement was needed in correctly answering questions related to enthalpy and heat flow in thermodynamic systems, as well as having a solid background in calculus-based derivations related to enthalpy. Based on the assessment results, to further strengthen the student's calculus background and ensure success, the faculty decided to restructure their teaching methods in CHEM 5310. A thorough review of basic differential and integral calculus was included, along with their applications to thermodynamic variables, that would enable the students to perform calculations and derivations correctly and comfortably. Additionally, the faculty decided to hold a limited number of tutoring sessions each week to address the student's questions on thermodynamic concepts, with a focus on enthalpy-related calculations and derivations. The improvement measures proposed during AY 2017-2018 were reassessed in 2018-2019. Analysis of student performance for SLO-2 during AY 2018-2019 revealed that the improvement measures proposed in the previous academic year were successful. This was evidenced by 4 out of 4 total students (100%) achieving the criteria for success and exceeding the benchmark during AY 2018-2019. 2 students scored 4 points for each measurement tool, and the other 2 students scored 5 points on each measurement tool. To maintain program strength and continued student learning, the chemistry faculty decided to offer more tutoring sessions and collaborate with faculty from physics and mathematical sciences in tutoring students during daytime, evenings, and even on Saturdays. The improvement measures were reassessed in 2019-2020. Analysis of student performance during AY 2019-2020 indicated that the same level of success was maintained, as observed during the previous year. During AY 2019-2020, 2 out of 2 students (100%) exceeded the benchmark for both measurement tools for SLO-2, scoring 5 points for each measurement tool. This positive outcome affirmed that the learning improvement measures designed in 2018-2019 had been successfully implemented in 2019-2020.

SLO-3 was measured by the following tools: (1) Successful completion of research projects in Biochemistry and Bio-Organic Chemistry through the use of specific instrumentation in research; and (2) Publication of, at least, one article in a peer-reviewed journal. Analysis of student

performances indicated that all students (100%) exceeded the benchmark during AY 2017-2018 (2 out of 2 students) and AY 2018-2019 (2 out of 2 students), scoring either 4 or 5 points. However, there was a concern for AY 2019-2020. While all 4 students (100%) exceeded the benchmark for the first measurement tool, only 2 out of 4 students (50%) were deemed competent for the second measurement tool. Out of 4 total students, 1 student exceeded the benchmark for success, 1 student met the benchmark, while the remaining 2 students fell below the benchmark, as they did not submit any articles for publication in a peer-reviewed journal. One of the students had health-related issues, which may have impacted the amount of time and energy required toward a full-length publication. Assessment of the 2019-2020 results prompted research advisors to work closely with their students to ensure the publication of at least one short review article, per student, in a peer-reviewed journal, if the student was unable to publish a full-length research article. All students were encouraged to attend the newly created Writing Hub within the university, to obtain help in preparing their thesis and scientific articles for publication. Having at least one scientific publication at the Master's level is important for the students' present and future successes.

Assessment of the changes proposed in AY 2019-2020 with respect to SLO-3 in terms of its implementation during the following AY (2020-2021) showed improved student engagement and performance, as evidenced by higher scores. To improve on the second assessment tool (student's writing a research article writing followed by publication), research advisors actively engaged all 3 students following the Biochemistry Concentration and encouraged and enabled them to compile their respective project's data to create scholarly scientific articles. As recommended, all 3 students made appointments with personnel in the university's Writing Hub and met with them at least twice each month to get additional help with the formulation of their articles. Of the 3 students, 1 student prepared a full-length manuscript that has been reviewed within the department by faculty and will be submitted for publication soon. The remaining 2 students have already prepared short scholarly articles as preprints that are ready for peer review, following which the articles will be submitted for publication. This is a marked improvement over the non-participation of half of the total number of students in the previous year, in terms of article/manuscript preparation efforts. Additionally, it was determined that all 3 students following the Biochemistry Concentration exceeded the benchmark for the first measurement tool. These results for AY 2020-2021 for SLO-3 indicate that 100% of the students have at least met or exceeded the benchmark.

The overall improvement in student performances related to the three SLOs during AY 2017-2018, 2018-2019, and 2019-2020 showed that the faculty were successful in increasing student learning and the student learning experience; and effectively prepared the students to meet and/or exceed the minimum performance target. A total of 36 students and 21 faculty members were involved in this collaborative process. The Chemistry M.S. Program now has a framework and culture of student learning improvement to aid in its continued progress.