Academic Assessment Committee

CCSU

Central Connecticut State University

PROGRAM REPORT SUMMARY

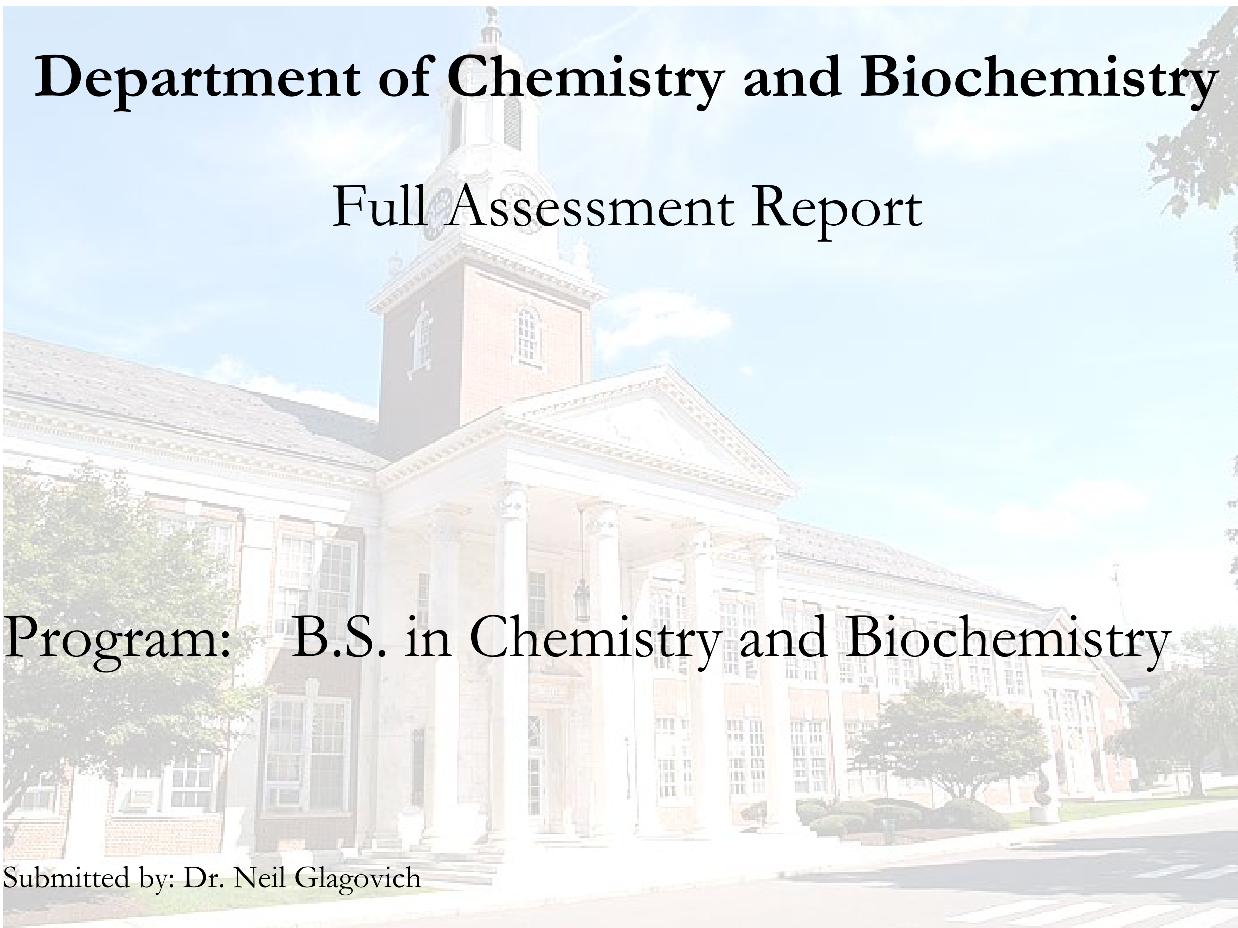
Department: Chemistry and Biochemistry	Report Type: FULL REPORT
Program Name and Level: BS in Chemistry and Biochemistry	Academic Year Data: 2020-21
Report Preparer: Neil Glagovich	Date Completed: 02/22/2022
Date of Last Program Review:	Semester of Next Program Review: currently under review

Program Assessment Question	Response
1) **URL**: Provide the URL where the Learning Outcomes (LO) can be viewed.	https://www.ccsu.edu/chemistry/programs.html https://www2.ccsu.edu/program/Chemistry_BS https://www2.ccsu.edu/program/Biochemistry_BS
2) **Assessment Instruments**: Please list the source(s) of the data/evidence, other than GPA, that is/are used to assess the stated outcomes? (e.g., capstone course, portfolio review and scoring rubric, licensure examination, etc.)	LO#1: DUCK instrument (CHEM 432) LO#2: Multi-Step Synthesis Report (CHEM 213) Advanced NMR Laboratory Report (CHEM 316) Titanocene Laboratory Report (CHEM 462) Safety Quiz (CHEM 238) LO#3: Poster Presentation (CHEM 332) Oral Presentation (CHEM 432)
3) **Interpretation**: Who interprets the evidence? (e.g., faculty, Admin. assistant, etc.).	Chemistry and Biochemistry Faculty
4) **Results**: Using this year's Findings, list: a. The conclusion(s) drawn b. The changes that were or will be made as a result of those conclusion(s)	**LO#1 Chemistry and biochemistry graduates will have integrated the mathematical, conceptual, and theoretical knowledge necessary to solve chemical problems.** 1) The current results for LO#1 show that, in comparison to previous years, our graduates continue to demonstrate an overall good grasp of the fundamental concepts and theory of chemistry and the requisite mathematics. The programmatic change from a two-semester sequence of General Chemistry to a one-semester foundation course could have severely impacted student knowledge. However, the creation of two new foundation level courses more than compensated for any possible drop-off in performance. There does

	not seem to be a trend (up or down) of a change in student knowledge, in general. The strengths of our program continue to be in the analytical, inorganic, and organic sub-disciplines. The biggest weakness would be the results of the physical chemistry sub-discipline. There may be several reasons behind this: 1) it is not clear if our students have a fundamental math disadvantage that is not overcome by the required mathematics courses, and/or 2) due to low enrollments, the preferred physical chemistry course for the ACS certified Chemistry program (CHEM 321) was cancelled in Fall 2020; most students replaced that course with CHEM 320 (which is meant for Biochemistry majors), and does not have the depth of coverage in kinetics and thermodynamics as CHEM 321. 2) The results of the latest academic year (Table A1.1) closely match the results from the previous four years (Table A1.2). Nearly 90% of our graduates meet our requirement for this learning outcome as evidenced by the 100% placement rate of our graduates in industry and graduate programs. **LO#2 Chemistry and biochemistry graduates will apply the laboratory and safety skills necessary for the synthesis, isolation, quantification, and identification of chemical compounds.** 1) This LO measures the (arguably) most important and most challenging aspect of a chemical education. Can you make (in good yield), purify, and identify chemical substances? Can you do this as safely as possible? Prior to academic year 2019-2020, roughly 80% of our graduates exhibited the qualities measured in the LO. Although this is not as high a percentage as we should like, it is much better than we have experienced in the recent past. Currently, our students' strengths are in implementing the necessary protocols for the safe handling of chemical substances (as it has been in the past). Our student weaknesses are everything else. This is the result of the non-standard way that information has been transmitted to our current students (online learning). 2) The results of the latest academic year (Table A2.1) show a much lower level of mastery than in previous years. The decline in student performance is alarming (Table A2.2). The noticeable drop in academic years 2019-2021 may be attributable to the impact of online learning versus hands-on in-the-lab student experience. It is impossible to teach laboratory skills without reinforcing that information through a hands-on experience. Many of the faculty have commented on substandard student laboratory skills. However, there is not much we can do about this cohort at this time. We must accept the fact that we will graduate students with below par abilities in the laboratory. Fortunately (or unfortunately), all other institutions of higher education are experiencing this same trend. With a return to on-ground learning, it will be interesting to see if this trend reverses itself naturally. **LO#3 Chemistry and biochemistry graduates will participate in collaborative research projects, exhibit the ethical behavior expected of professional chemists, and be able to effectively communicate research results.** 1) Undergraduate research is by far the most important advantage that our graduates have over graduates of other institutions of comparable size. Our students work directly with faculty on original research projects and are expected to present their results at either a regional or national meeting of the American Chemical Society. Our current results are not a reflection of the program's ability to train chemists. The COVID-19 pandemic greatly reduced the number of students participating in undergraduate research, and those that did, were unable to

	spend the required time on campus with faculty for obvious reasons. The students' strong point (ability to communicate what their research entails through a poster presentation) continues to result from a close collaboration with faculty on their projects. However, a tremendous amount of remediation has taken place over the past two academic years due to the lack of laboratory experience from which our current students have suffered. The main weakness (ability to independently plan their work) is a constant theme over the years. A jarring weakness has to do with ethical behavior: there are more students trying to "fudge" rather than simply presenting their results. Is this a result of the deterioration of western culture or a failure on the Department's behalf? Unfortunately, the Department has yet to receive advice from the ACS-CPT on assessing ethical behavior. 2) Prior to academic year 2019-2020, roughly 90% of our graduates were able to successfully communicate their research results at national and regional meetings of the ACS. The pandemic drastically reduced the number of students participating in research, and the low number of students calls the statistics for academic years 2019-2021 into question. The faculty remain unconvinced that the statistics are showing a decline in our ability to train undergraduates. Let's take a wait and see approach here.
5) **<u>Strengths</u>**: List ways in which your assessment process is working well.	LO#1: The DUCK is working as a fantastic way to assess total knowledge of chemistry. LO#2: Instruments used here are efficient and useful. LO#3: Instruments used here are efficient and useful.
6) **<u>Improvements</u>**: List ways in which your assessment process needs to improve based on student data (A brief summary of changes to assessment plan can be reported here).	LO#1: None indicated at this time. LO#2: Impact of COVID 19 makes analysis of statistics difficult. No change warranted at this time. LO#3: Impact of COVID 19 makes analysis of statistics difficult. No change warranted at this time.
7) **<u>General Education Assessment</u>**: Please list the department faculty who have participated in our General Education Assessment Initiative. (For graduate degree programs, please type N/A.)	Tom Burkholder, Barry Westcott, and Guy Crundwell.

Central Connecticut State University



Department of Chemistry and Biochemistry

Full Assessment Report

Program: B.S. in Chemistry and Biochemistry

Submitted by: Dr. Neil Glagovich

2021-2022

PREAMBLE

1) *Brief description about degree*

The Chemistry and Biochemistry Department offers B.S. Chemistry and B.S. Biochemistry degrees, which are professionally accredited by the American Chemical Society. Our students enjoy student-faculty interactions, research opportunities, an active chemistry community (including a student organized Chemistry Club), and comparatively low tuition making us an appealing educational option.

The Department of Chemistry & Biochemistry offers a supportive environment; our upper-level courses are small enough to allow regular discussion with faculty and peers, and our Chemistry Club hosts social events, works on community engagement and outreach, and plans trips to national meetings where our students present original research.

In addition to our teaching labs, the department has advanced chemical instrumentation laboratories that include three major instruments purchased through National Science Foundation grants. Unlike at larger schools, where undergraduates typically work for a graduate student, our students work directly with faculty on original projects. Many of these students give presentations at regional or national conferences, and many have co-authored peer-reviewed publications.

2) *Most significant changes made to degree or program, curricular or programmatic, based on results from assessment activities.*

In 2016, the American Chemical Society Committee on Professional Training (ACS-CPT) altered the curriculum necessary for certification such that each sub-discipline of chemistry (analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry) required one foundational course and one upper-level course. In response, the Chemistry and Biochemistry Department made the following changes:

1. The two-semester sequence of general chemistry was no longer offered. Instead, a one-semester general chemistry course with an accompanying laboratory (CHEM 161 & 162) would serve as the entry point into the one-semester foundation courses in each discipline (CHEM 200, 210, 260, 321, and 354). There is no longer a sequence that must be followed in these foundation courses. For instance, *Foundations of Organic chemistry* (CHEM 210) can be taken before, during, or after any other foundation course (e.g., *Foundations of Analytical*

Chemistry, CHEM 200). This change required a total rethinking of the curriculum offered in each course because each must be able to stand alone and cannot require any other course (except CHEM 161 & 162) as a prerequisite.

2. The changes implemented above required that the two-semester organic chemistry sequence (CHEM 210 & 212) had to be altered such that the foundation course (CHEM 210) contains all the organic chemistry content because other majors were no longer requiring the two-semester sequence. This allowed the Department to change CHEM 212 into an upper-level course focusing on organic synthesis. This change permitted the Department to have both a foundation and upper-level course in organic chemistry.
3. Two sub-disciplines of chemistry (analytical and inorganic chemistries) did not have foundation level courses. This content was delivered in the second semester of the old two-semester sequence of general chemistry. To rectify this situation, the Department created two new courses (CHEM 200 *Foundations of Analytical Chemistry* and CHEM 260 *Foundations of Inorganic Chemistry*). The upper-level courses in these sub-disciplines already existed (CHEM 402 & 460).

The Department of Chemistry and Biochemistry was now required to assess Foundation level courses that, until this point, had not existed. After several unsuccessful attempts, the Department settled on using the Diagnostic of Undergraduate Chemistry Knowledge (DUCK) for this purpose. This useful instrument allows the Department to assess each sub-discipline independently while also assessing the overall chemical knowledge of our graduates.

The major curricular change required by the ACS-CPT also included changes to the suggested learning outcomes for our programs. These learning outcomes were updated in 2016, and again in 2019 to reflect continuing refinements made by the ACS-CPT.

1: Learning Outcomes

The Department of Chemistry and Biochemistry is accredited by the American Chemical Society (ACS), one of the world's largest scientific organizations with more than 152,000 members in 130+ countries. The ACS was founded in 1876 and chartered by the U.S. Congress, with a continuing mission to advance the broader chemistry enterprise and its practitioners for the benefit of Earth and its people. Their vision is to improve people's lives through the transforming power of chemistry. The Department offers B.S. degrees in Chemistry and Biochemistry, both of which follow certification procedures of and periodic reviews by the ACS Committee on Professional Training (CPT).

The ACS-CPT suggests the following learning outcomes which have been adopted by the Department:

1. Chemistry and biochemistry graduates will have integrated the mathematical, conceptual, and theoretical knowledge necessary to solve chemical problems.

2. Chemistry and biochemistry graduates will apply the laboratory and safety skills necessary for the synthesis, isolation, quantification, and identification of chemical compounds.

3. Chemistry and biochemistry graduates will participate in collaborative research projects, exhibit the ethical behavior expected of professional chemists, and be able to effectively communicate research results.

The learning outcomes are available to students and other interested parties at these CCSU webpages:

https://www.ccsu.edu/chemistry/programs.html

https://www2.ccsu.edu/program/Chemistry_BS

https://www2.ccsu.edu/program/Biochemistry_BS

The undergraduate curriculum is mapped to the learning outcomes in Table 1.1. Assessment of each learning outcome will typically take place in a course where mastery is expected (3 on the scaffolding scale in Table 1.1). However, there may be exceptions to this general rule for strategic reasons. We are assessing all majors in all outcomes. This may skew some of the assessment results since there will be non-graduating students in each year who may not have been exposed to the entire curriculum. Any deficiencies shown may well be addressed in courses that have yet to be taken by these students. Regardless, the assessment results will be used to modify the curriculum in such a fashion as to address those deficiencies.

One final note on assessment: each learning outcome is either introduced, reinforced, or mastered in different courses. A deficiency in student outcomes from the yearly assessment necessitates that all courses upstream of the ultimate mastery course (where assessment takes place) will have to be involved in any curricular or programmatic changes.

1: LEARNING OUTCOMES

Table 1.1 Curriculum map for learning outcomes. Courses in purple are common to both the Chemistry and Biochemistry degree programs. Courses in red are specific to the Chemistry degree program while courses in blue are specific to the Biochemistry degree program. Scaffolding: 1-introduce, 2-reinforce, 3-mastery.

		LO #1	LO #2	LO #3
Chemistry Core	CHEM 161 *General Chemistry*	1		
	CHEM 162 *General Chemistry Laboratory*		1	1
	CHEM 200 *Foundations of Analytical Chemistry*	2		
	CHEM 201 *Foundations of Analytical Chemistry Laboratory*		2	1
	CHEM 210 *Organic Chemistry I - Foundations*	2		
	CHEM 211 *Organic Chemistry I Laboratory - Foundations*		2	1
	CHEM 212 *Organic Synthesis*	2		
	CHEM 213 *Organic Chemistry II Laboratory - Synthesis*		2	1
	CHEM 238 *Introduction to Research*		2	2
	CHEM 260 *Foundations of Inorganic Chemistry*	2		
	CHEM 316 *Spectrometric Identification of Organic Compounds*	3	3	
	CHEM 332 *Chemical Literature*			2
	CHEM 432 *Chemistry Seminar*			3
	CHEM 438 *Undergraduate Research*		3	3
Upper-Level Electives	CHEM 320 *Biophysical Chemistry*	2		
	CHEM 321 *Physical Chemistry of Thermodynamics & Kinetics*	2		
	CHEM 322 *Physical Chemistry of Quantum & Statistical Mechanics*	2		
	CHEM 323 *Physical Chemistry Laboratory*		3	2
	CHEM 354 *Foundations of Biochemistry*	2		
	CHEM 402 *Instrumental Methods in Analytical Chemistry*	3	3	
	CHEM 406 *Environmental Chemistry*	2	2	
	CHEM 455 *Biochemistry Laboratory*		2	2
	CHEM 456 *Toxicology*	2		
	CHEM 458 *Advanced Biochemistry*	3		
	CHEM 460 *Inorganic Symmetry & Spectroscopy*	3		
	CHEM 462 *Inorganic Chemistry Laboratory*		3	2

2: FINDINGS

All learning outcomes will be assessed in terms of ***meets*** or ***does not meet*** the criteria set for each method of evaluation. Each Learning outcome will be assessed according to the following:

LO#1 Chemistry and biochemistry graduates will have integrated the mathematical, conceptual, and theoretical knowledge necessary to solve chemical problems.

This outcome is assessed in CHEM 432 "Chemistry Seminar" which serves as a capstone course for graduating seniors. The Department uses the Diagnostic of Undergraduate Chemistry Knowledge (DUCK), an instrument designed by the ACS Division of Chemical Education to test the foundational knowledge in the major subdisciplines of chemistry: analytical, biochemical, inorganic, organic, and physical chemistries. Although the total score on the instrument is important, of more use to the Department is the breakdown of scores for each sub-discipline. This can direct where in the curriculum modifications to improve student learning should take place. Although LO#1 does not map to this course, it is convenient for the assessment of this learning outcome since all majors must take this course in the second semester of their senior year. Deficiencies indicated from this assessment will have to be addressed in the courses where LO#1 is introduced or reinforced (CHEM 161, 200, 210, 212, 260, 320, 321, 322, and 354).

Student learning is evaluated based upon the raw score for the instrument and the scores for each subsection (analytical, biochemical, inorganic, organic, and physical chemistry sections). The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. The DUCK is broken into scenarios where information is presented to the student and questions about the scenario are to be answered. To be successful, the student must synthesize the mathematical, conceptual, and theoretical chemical background gained through the degree program to holistically answer the questions. The DUCK serves as an exit examination where students demonstrate their readiness to enter the chemistry profession. The data for LO#1 are provided in Appendix 1. Unfortunately, the instrument is the property of the American Chemical Society and cannot be lawfully reproduced. The instrument is available for inspection upon request.

LO#2 Chemistry and biochemistry graduates will apply the laboratory and safety skills necessary for the synthesis, isolation, quantification, and identification of chemical compounds.

A. **Portfolio: Multi-Step Synthesis Report (CHEM 213).** Organic Synthesis Laboratory (CHEM 213) is a course where undergraduates perform an eight-week-long multi-step organic synthesis. The final report includes information regarding the synthetic methodology used in each step of the total synthesis, the techniques used in the purification of each product along the way, and evidence (spectroscopic and physical) detailing the structure of the target molecule. The criteria used for evaluation include accurately describing the experimental procedure (including purification), the yield of the chemical reaction, and a discussion of the expected structure (physical and spectroscopic evidence) resulting from each step. The laboratory report becomes a part of the student's portfolio which is used for

assessment purposes.
Student learning is evaluated based upon the rubric (LO#2A-C) in Appendix 2. The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. All student artifacts are maintained by the Department for five years.

B. **Portfolio: Advanced NMR Laboratory Report (CHEM 316).** Spectrometric Identification of Organic Compounds (CHEM 316) emphasizes the use of mass spectrometry and infrared, ultraviolet/visible, and nuclear magnetic resonance spectroscopies in the elucidation of the structures of organic compounds. The final experiment in the course involves the use of two-dimensional NMR techniques to identify an unknown organic compound. In addition, the students must fully characterize the unknown compound using infrared and ultraviolet/visible spectroscopies and mass spectrometry. The laboratory report becomes a part of the student's portfolio which is used for assessment purposes.
Student learning is evaluated based upon the rubric (LO#2A-C) in Appendix 2. The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. All student artifacts are maintained by the Department for five years.

C. **Portfolio: Titanocene Laboratory Report (CHEM 462).** Inorganic Chemistry Laboratory (CHEM 462) is concerned with the synthesis and characterization of inorganic compounds. Topics include air-sensitive manipulation, coordination chemistry and chemistry of materials. Each student will prepare an air-sensitive titanocene compound and write a report detailing the synthesis and characterization of this compound. The laboratory report becomes a part of the student's portfolio which is used for assessment purposes.
Student learning is evaluated based upon the rubric (LO#2A-C) in Appendix 2. The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. All student artifacts are maintained by the Department for five years.

D. **Safety Quiz (CHEM 238).** Before undertaking undergraduate research, students must read *Safety in Academic Undergraduate Chemistry Laboratories*, a publication of the ACS. The student must also complete a 35-question quiz on the topic. A score greater than 70% is considered meeting the requirement. The instrument used in the assessment is given in Appendix 2.

The data for LO#2 are provided in Appendix 2 (Tables A2.1-A2.3).

LO#3 Chemistry and biochemistry graduates will participate in collaborative research projects, exhibit the ethical behavior expected of professional chemists, and be able to effectively communicate research results.

2: FINDINGS

A. **Portfolio: Poster Presentation (CHEM 332).** All chemistry and biochemistry majors are required to take CHEM 332 (Chemical Literature) At the completion of CHEM 332 each student must prepare a poster presentation of the undergraduate research results obtained in CHEM 238 (Introduction to Research). This poster becomes a part of the student's portfolio which is used for assessment purposes. Student learning is evaluated based upon the rubric (LO#3A) in Appendix 3. The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. All student artifacts are maintained by the Department for five years.

B. **Portfolio: Written version of Oral Presentation (CHEM 432).** All chemistry and biochemistry majors are required to take CHEM 432 (Chemistry Seminar). At the completion of CHEM 432 each student must prepare a final paper and give an oral presentation of the undergraduate research results obtained in CHEM 438 (Undergraduate Research). This final paper becomes a part of the student's portfolio which is used for assessment purposes.
Student learning is evaluated based upon the rubric (LO#3B) in Appendix 3. The evaluation is completed by the instructor for the course and reported to the Department Assessment Committee. All student artifacts are maintained by the Department for five years.

The data for LO#3 are provided in Appendix 3 (Tables A3.1-A3.2).

3: ANALYSIS

For each outcome:

1) *Within the context of data from past years, describe what these current results mean, including an identification of patterns of students' strengths and weaknesses across the program.*

2) *Describe how the results have changed over time.*

LO#1 Chemistry and biochemistry graduates will have integrated the mathematical, conceptual, and theoretical knowledge necessary to solve chemical problems.

1) The current results for LO#1 show that, in comparison to previous years, our graduates continue to demonstrate an overall good grasp of the fundamental concepts and theory of chemistry and the requisite mathematics. The programmatic change from a two-semester sequence of General Chemistry to a one-semester foundation course could have severely impacted student knowledge. However, the creation of two new foundation level courses more than compensated for any possible drop-off in performance. There does not seem to be a trend (up or down) of a change in student knowledge, in general. The strengths of our program continue to be in the analytical, inorganic, and organic sub-disciplines. The biggest weakness would be the results of the physical chemistry sub-discipline. There may be several reasons behind this: 1) it is not clear if our students have a fundamental math disadvantage that is not overcome by the required mathematics courses, and/or 2) due to low enrollments, the preferred physical chemistry course for the ACS certified Chemistry program (CHEM 321) was cancelled in Fall 2020; most students replaced that course with CHEM 320 (which is meant for Biochemistry majors), and does not have the depth of coverage in kinetics and thermodynamics as CHEM 321.
2) The results of the latest academic year (Table A1.1) closely match the results from the previous four years (Table A1.2). Nearly 90% of our graduates meet our requirement for this learning outcome as evidenced by the 100% placement rate of our graduates in industry and graduate programs.

LO#2 Chemistry and biochemistry graduates will apply the laboratory and safety skills necessary for the synthesis, isolation, quantification, and identification of chemical compounds.

1) This LO measures the (arguably) most important and most challenging aspect of a chemical education. Can you make (in good yield), purify, and identify chemical substances? Can you do this as safely as possible? Prior to academic year 2019-2020, roughly 80% of our graduates exhibited the qualities measured in the LO. Although this is not as high a percentage as we should like, it is much better than we have experienced in the recent past. Currently, our students' strengths are in implementing the necessary protocols for the safe handling of chemical substances (as it has been in the past). Our student weaknesses are

everything else. This is the result of the non-standard way that information has been transmitted to our current students (online learning).

2) The results of the latest academic year (Table A2.1) show a much lower level of mastery than in previous years. The decline in student performance is alarming (Table A2.2). The noticeable drop in academic years 2019-2021 may be attributable to the impact of online learning versus hands-on in-the-lab student experience. It is impossible to teach laboratory skills without reinforcing that information through a hands-on experience. Many of the faculty have commented on substandard student laboratory skills. However, there is not much we can do about this cohort at this time. We must accept the fact that we will graduate students with below par abilities in the laboratory. Fortunately (or unfortunately), all other institutions of higher education are experiencing this same trend. With a return to on-ground learning, it will be interesting to see if this trend reverses itself naturally.

LO#3 Chemistry and biochemistry graduates will participate in collaborative research projects, exhibit the ethical behavior expected of professional chemists, and be able to effectively communicate research results.

1) Undergraduate research is by far the most important advantage that our graduates have over graduates of other institutions of comparable size. Our students work directly with faculty on original research projects and are expected to present their results at either a regional or national meeting of the American Chemical Society. Our current results are not a reflection of the program's ability to train chemists. The COVID-19 pandemic greatly reduced the number of students participating in undergraduate research, and those that did, were unable to spend the required time on campus with faculty for obvious reasons. The students' strong point (ability to communicate what their research entails through a poster presentation) continues to result from a close collaboration with faculty on their projects. However, a tremendous amount of remediation has taken place over the past two academic years due to the lack of laboratory experience from which our current students have suffered. The main weakness (ability to independently plan their work) is a constant theme over the years. A jarring weakness has to do with ethical behavior: there are more students trying to "fudge" rather than simply presenting their results. Is this a result of the deterioration of western culture or a failure on the Department's behalf? Unfortunately, the Department has yet to receive advice from the ACS-CPT on assessing ethical behavior.
2) Prior to academic year 2019-2020, roughly 90% of our graduates were able to successfully communicate their research results at national and regional meetings of the ACS. The pandemic drastically reduced the number of students participating in research, and the low number of students calls the statistics for academic years 2019-2021 into question. The faculty remain unconvinced that the statistics are showing a decline in our ability to train undergraduates. Let's take a wait and see approach here.

4: USE OF RESULTS

For each outcome:

1) *Describe how the results have been used to make curricular or programmatic changes over the last five years.*

2) *Clearly articulate the relationship between the results and the curricular/programmatic adjustment.*

LO#1 Chemistry and biochemistry graduates will have integrated the mathematical, conceptual, and theoretical knowledge necessary to solve chemical problems.

1) The last major change to the curriculum occurred in 2016, and it had nothing to do with assessment (this was dictated from on high by the ACS-CPT). This curriculum change involved reducing the General Chemistry portion of the curriculum from a two-semester sequence to a one-semester introductory course. In tandem with that change, the courses in each sub-discipline were reorganized to generate a foundational course and an upper-level course. Regardless of the impetus for the change, the Department continues to produce high-quality graduates with an excellent foundation in chemistry principles. Having said that, there is a need for improvement in the physical chemistry aspect of our undergraduate education. We are currently investigating whether this can be fixed with a change in the mathematics requirement of our programs or if changes are required in the CHEM 230, 231, and 232 courses. The sticking point here is the change that the Mathematics Department implemented in Fall 2019 involving math placement testing and an overhaul of the MATH 101 (now two courses: MATH 102 or 103 depending upon the major). Dr. Burkholder is planning assessment tools to see if we can divine where the problem lies.
2) The changes to the program in 2016 did not have a measurable effect on student learning.

LO#2 Chemistry and biochemistry graduates will apply the laboratory and safety skills necessary for the synthesis, isolation, quantification, and identification of chemical compounds.

1) No changes to the curriculum with respect to this LO.
2) No changes in the works. The Department would like to gather assessment data for three more years (to clear the system of students affected by the pandemic) to see if any trends in the assessment data are real or artifacts.

LO#3 Chemistry and biochemistry graduates will participate in collaborative research projects, exhibit the ethical behavior expected of professional chemists, and be able to effectively communicate research results.

1) No changes to the curriculum with respect to this LO.
2) No changes in the works. The Department would like to gather assessment data for three more years (to clear the system of students affected by the pandemic) to see if any trends in the assessment data are real or artifacts

5. Departmental Assessment Plan

AY 2016-2017

- Implement changes to program required by ACS-CPT.
- Implement new learning outcomes.
- Continue to assess each learning outcome as in previous years. Include the DUCK for LO#1.
- Per the Departmental Assessment Coordinator, instructors of CHEM 432 are required to deliver the DUCK during finals week. The data must be transmitted to Dr. Glagovich before the end of the spring semester.
- Per the Departmental Assessment Coordinator, instructors of CHEM 213, 316, and 462 must use the supplied rubric for the assessment of certain lab reports. These include for CHEM 213 the multi-step synthesis report, for CHEM 316 the advanced NMR laboratory report, and for CHEM 462 the titanocene laboratory report.
- Per the Departmental Assessment Coordinator, instructors of CHEM 238 must administer the Departmental Laboratory Safety Quiz after students have read the *Safety in Academic Undergraduate Chemistry Laboratories*, a publication of the ACS.
- Per the Departmental Assessment Coordinator, instructors of CHEM 332 must use the supplied rubric for the assessment of the poster presentation.
- Per the Departmental Assessment Coordinator, instructors of CHEM 432 must use the supplied rubric for the assessment of the oral and written presentation.

AY 2019-2020

- Select a faculty member to serve as assessment coordinator. This is currently Neil Glagovich.

AY 2020-2021

- The assessment coordinator will create a file system on Teams to store all student artifacts used in assessment.
- A study group tasked with looking at the content of general chemistry was formed. This study group will report to the academic assessment coordinator in Spring 2022.

APPENDIX 1 – LO#1

The evaluation instrument is purchased from the ACS Division of Chemical Education. It is illegal to photocopy or post the instrument to the web. Interested parties can contact the chair of the Chemistry and Biochemistry Department to schedule an appointment to inspect the document.

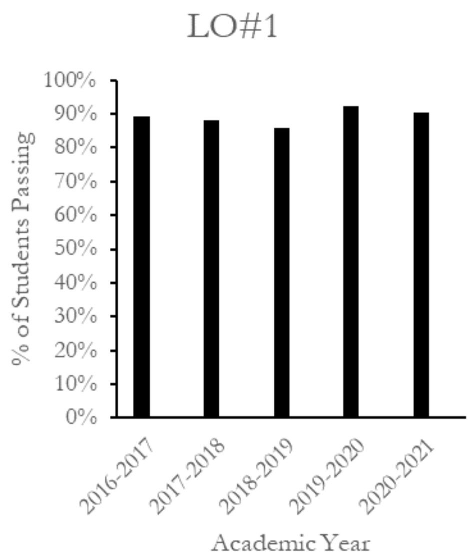
The rubric for evaluating LO#1 involves scoring each scenario of the DUCK for each subdiscipline (analytical (A), biochemical (B), inorganic (I), organic (O), and physical (P) chemistry. It is possible to not pass a subdiscipline and still meet the overall criteria for LO#1 (total score over 70%).

Table A1.1 Percentage of students (AY 2020-2021) mastering each subdiscipline of chemistry.

Number of Students (N)	subdiscipline (A)	(B)	(I)	(O)	(P)	Average Score
21	100%	86%	95%	95%	76%	90%

Table A1.2 Percentage of students mastering LO#1.

Academic Year	N	M	DNM	YA
2016-2017	19	17	2	89%
2017-2018	25	22	3	88%
2018-2019	14	12	2	86%
2019-2020	13	12	1	92%
2020-2021	21	19	2	90%
5YA:				89%



N: Number of students
Meets (M): ≥ 70% on DUCK
Does Not Meet (DNM): ≤ 70% on DUCK
YA: yearly average of students meeting outcome
5YA: five-year average of students meeting outcome

APPENDIX 2 - LO#2

The instructions to students preparing their written laboratory reports are given below.

Chemistry Laboratory – Expectations for lab reports

CCSU Faculty

If all else fails, read the instructions – Anon

The following are a set of instructions concerning the preparation of lab reports. Lab reports will be graded out of 25 points, and the subtraction of points will be based to a significant extent on failure to follow these requirements.

Submission Deadlines: Reports must be submitted by the end of the lab session associated with the due date. A late penalty of 5 points per week will be assessed; the first week begins at the end of the lab session if a report is not submitted.

Format and Style: All lab reports should be submitted using a standard format, as follows.

(1) The font used should be 12 point and sans-serif.
(2) Margins should be 1/2", text should be double spaced and be justified in a two-column format.
(3) The past tense and passive voice should be used throughout the report. The correct style is "The mixture *was heated*", not "I heated the mixture" or "Heat the Mixture". You are reporting on what *was done*. This style is ubiquitous in scientific journals, and it is important that you get into the habit of writing in this style. Failure to write in this style is a major reason for losing a significant number of points on lab reports.
(4) All parts of the report should be written as cohesive paragraphs, and should use good grammar, spelling and punctuation. BE SURE TO PROOFREAD YOUR REPORT CAREFULLY. Subheadings (Introduction, Procedure, *etc.*) should be emphasized in bold text, and the first line of the paragraph should immediately follow the subheading on the same line.
(5) Use the clearest and most concise language possible. Do not pad the report with unnecessary details. Your lab report should contain 500 words or less (not including the Abstract).

(6) **Inclusion of Spectra** In some cases, spectroscopic data may need to be included as part of the report. The Figure Caption should clearly identify the compound corresponding to the spectrum. Spectra should be included as a numbered figure, and any description of the data should reference the appropriate figure number. For example: The IR spectrum of benzaldehyde (Fig. 1) showed peaks characteristic of an aldehyde…

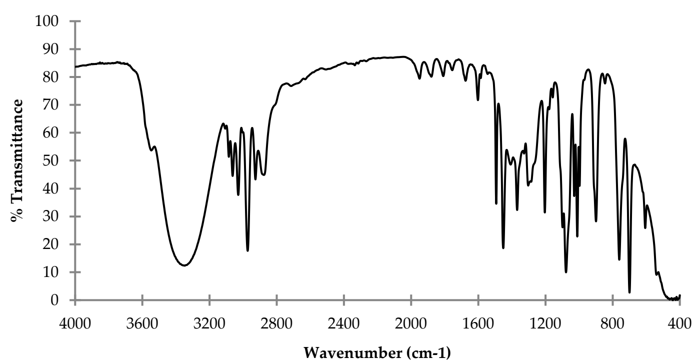


Figure 1. Infrared Spectrum of 1-phenyl-1-ethanol.

Spectra should be prepared using an appropriate plotting program such as Excel. The data should be presented with a clear background (no shading or grid), and axes should be clearly labeled with appropriate units.

APPENDIX 2 - LO#2

Components of the Laboratory Report: The laboratory report should always contain the following components, in the specified order.

(1) **Title (including Author and Date):** Centered, and in **bold typeface**. The date must accurately reflect the date on which the report is to be submitted.

(2) **Abstract.** The Abstract is a very short summary of the paper which must stand on its own because many journals and databases provide the abstract without the rest of the paper. The reader then uses the abstract to help decide whether it is worth the effort to look at the main part of the paper. For our purposes, the Abstract must include the identity of the unknown along with the unknown number. It is usually easiest to write the Abstract after the rest of the paper is done. Must have one-inch margins.

(3) **Introduction**: A BRIEF explanation of the purpose of the experiment. If the goal is to identify an unknown substance via a particular spectroscopic technique, then state so. A clear computer-drawn structure of the unknown substance (prepared with a program such as ChemSketch (which is available on the computers in the Science Computing Lab, 2nd floor Copernicus Hall) must be included.

(4) **Experimental:** The experimental section should clearly describe how the experiment was performed (note past tense, passive voice), and it should include important observations. When appropriate, data involving percent yield should be included. If spectroscopic data are to be included in a report, they should be included as a numbered figure (as described below).

(5) **Results and Discussion:** This section should briefly summarize the outcome of the experiment and the relevance of any data collected. If spectroscopic data are to be included in the report, the spectra and their significance should be included in this section. A brief explanation of errors or problems may be included but are not necessary unless they are particularly important to the description of the outcome of the experiment. For example, significant spillage or a lost product due to a broken flask could be mentioned. Non-specific statements such as "The yield may have been low due to human error" should be avoided.

APPENDIX 2 - LO#2

The rubric for LO#2A-C is given below. Each facet of the learning outcome is scored. An average of 70% or above is considered meeting LO#2A-C.

Facet of LO	Meets (3-5 points)	Does Not Meet (0-2 points)
Synthesis of Chemical Compound	Student wrote out the synthetic procedure for all synthetic in their own words. Chemical drawing software was sued to generate a synthetic scheme accurately portraying the procedure.	Student either did not use their own words, did not consistently use the correct tense or voice, or did not do this for all synthetic steps.
Isolation of Chemical Compound	Student clearly understood the appropriate methodology to use in the purification of each compound, carefully carried out each purification, and achieved the expected yield of each reaction.	Student did not understand or use the appropriate separation technique or was outside of the standard deviation of the expected yield for the compound.
Quantification of Chemical Compound	Student correctly calculated the percent yield of the reaction or otherwise determined the concentration of the product compound using either a spectroscopic method or titration.	The student was unable to quantify the product either because it was impure, or the quantification method was implemented improperly.
Identification of Chemical Compound	Student obtained the appropriate physical evidence of the structure of the chemical compound. This may include melting point, boiling point, refractive index, and/or optical rotation. The obtained values agreed with literature values. Spectroscopic evidence (MS, IR, UV/Vis or NMR) were adequately interpreted and consistent with the structure.	Student did not obtain appropriate physical or spectroscopic evidence, such physical evidence was not in agreement with literature values, or spectral evidence was not consistent with the expected structure.
Format	Student used correct font and font size, margins, spacing, columns, and justification. Student used past tense passive voice throughout. Grammar, spelling, and punctuation were correct throughout.	Student did not use correct format throughout.
Score:	**/ 25 points**	17-25 Meets Expectations ≤17 Does Not Meet Expectations

APPENDIX 2 - LO#2

The instrument for LO#2D (Laboratory Safety) is given below.

1. Flammable materials, like alcohol, should never be dispensed or used near A. an open door. B. an open flame. C. another student. D. a sink.	7. If a lab experiment is not completed, you should A. discuss the issue with your instructor. B. sneak in after school and work alone. C. finish while eating lunch. D. make up some results.
2. If a laboratory fire erupts, immediately A. notify your instructor. B. run for the fire extinguisher. C. throw water on the fire. D. open the windows.	8. You are heating a substance in a test tube. Always point the open end of the tube A. toward yourself. B. toward your lab partner. C. toward another classmate. D. away from all people.
3. Approved eye protection devices (such as goggles) are worn in the laboratory A. to avoid eye strain. B. to improve your vision. C. only if you don't have corrective glasses. D. at all times.	9. You are heating a piece of glass and now want to pick it up. You should A. use a rag or paper towels. B. pick up the end that looks cooler. C. use tongs. D. pour cold water on it.
4. If you wear contact lenses in the school laboratory, A. take them out before starting the lab. B. you do not have to wear protective goggles. C. advise your science instructor that you wear contact lenses. D. keep the information to yourself.	10. You have been injured in the laboratory (cut, burn, etc.). First you should A. visit the school nurse after class. B. see a doctor after school. C. tell the science instructor at once. D. apply first aid yourself.
5. If you do not understand a direction or part of a lab procedure, you should A. figure it out as you do the lab. B. try several methods until something works. C. ask the instructor before proceeding. D. skip it and go on to the next part.	11. When gathering glassware and equipment for an experiment, you should A. read all directions carefully to know what equipment is necessary. B. examine all glassware to check for chips or cracks. C. clean any glassware that appears dirty. D. All the above.
6. After completing an experiment, all chemical wastes should be A. left at your lab station for the next class. B. disposed of according to your instructor's directions. C. dumped in the sink. D. taken home.	12. You want to place a piece of glass tubing into a rubber stopper after the tubing has been fire polished and cooled. This is best done by A. lubricating the tubing with water or glycerin. B. using a towel or cotton gloves for protection. C. twisting the tubing and stopper carefully. D. All the above.

Appendix 2 - LO#2

13. Personal eyeglasses provide as much protection as
    A. a face shield.
    B. safety glasses.
    C. splashproof chemical goggles.
    D. None of the above.
14. Long hair in the laboratory must be
    A. cut short.
    B. held away from the experiment with one hand.
    C. always neatly groomed.
    D. tied back or kept entirely out of the way with a hair band, hairpins, or other confining device.
15. In a laboratory, the following should not be worn.
    A. loose clothing.
    B. dangling jewelry.
    C. sandals.
    D. All the above.
16. The following footwear is best in the laboratory.
    A. sandals
    B. open-toed shoes
    C. closed-toed shoes
    D. shoes appropriate for the weather
17. Horseplay or practical jokes in the laboratory are
    A. always against the rules.
    B. okay.
    C. not dangerous.
    D. okay if you are working alone.
18. If a piece of equipment is not working properly, stop, turn it off, and tell
    A. the custodian.
    B. your lab partner.
    C. your best friend in the class.
    D. the science instructor.
19. If an acid is splashed on your skin, wash at once with
    A. soap.
    B. oil.
    C. weak base.
    D. plenty of water.
20. When you finish working with chemicals, biological specimens, and other lab substances, always
    A. treat your hands with skin lotion.
    B. wash your hands thoroughly with soap and water.
    C. wipe your hands on a towel.
    D. wipe your hands on your clothes.
21. Draw a diagram of your science room and label the locations of the following:
    - ☐ Fire Blanket
    - ☐ Fire Extinguisher(s)
    - ☐ Exits
    - ☐ Eyewash Station
    - ☐ Emergency Shower
    - ☐ Closest Fire Alarm Station
    - ☐ Waste Disposal Container(s)

True—False

	T	F	
22.	☐	☐	Hot glass looks the same as cold glass.
23.	☐	☐	All chemicals in the lab are to be considered dangerous.
24.	☐	☐	Return all unused chemicals to their original containers.
25.	☐	☐	Work areas should be kept clean and tidy.
26.	☐	☐	Pipets are used to measure and dispense small amounts of liquids. You should draw the liquid into the pipet using your mouth.
27.	☐	☐	Laboratory work can be started immediately upon entering the laboratory even if the instructor is not yet present.
28.	☐	☐	Never remove chemicals or other equipment from the laboratory.
29.	☐	☐	Chipped or cracked glassware is okay to use.
30.	☐	☐	Read all procedures thoroughly before entering the laboratory.
31.	☐	☐	All unauthorized experiments are prohibited.
32.	☐	☐	You are allowed to enter the chemical preparation/storage area any time you need to get an item.
33.	☐	☐	Laboratory coats should be worn during all lab activities.
34.	☐	☐	It's okay to pick up broken glass with your bare hands if the glass is placed in the trash.
35.	☐	☐	Never leave a lit burner unattended.

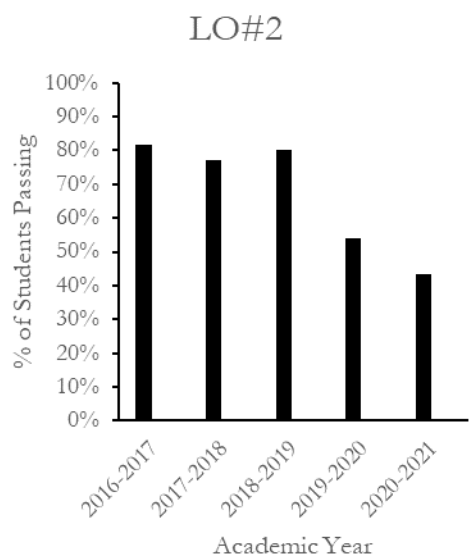
APPENDIX 2 - LO#2

Table A2.1 Percentage of students (AY 2020-2021) meeting each category of rubric for LO#2.

Number of Students (N)	Facet of LO#2A-C					Average Score
	Synthesis	Isolation	Quantification	Identification	Format	
23	43%	42%	35%	23%	72%	43%

Table A2.2 Percentage of students meeting LO#2A-C.

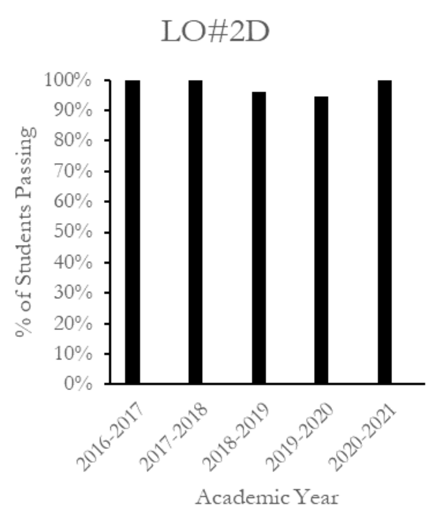
Academic Year	N	M	DNM	YA
2016-2017	22	18	4	82%
2017-2018	22	17	5	77%
2018-2019	20	16	4	80%
2019-2020	13	7	6	54%
2020-2021	23	10	13	43%
5YA:				67%



N: Number of students
Meets (M): ≥ 70% on rubric
Does Not Meet (DNM): ≤ 70% on rubric
YA: yearly average of students meeting outcome
5YA: five-year average of students meeting outcome

Table A2.3 Percentage of students meeting LO#2D.

Academic Year	N	M	DNM	YA
2016-2017	30	30	0	100%
2017-2018	29	29	0	100%
2018-2019	27	26	1	96%
2019-2020	18	17	1	94%
2020-2021	12	12	0	100%
5YA:				98%



APPENDIX 3 - LO#3

The rubric for LO#3A is given below. Each facet of the learning outcome is scored. An average of 62% or above is considered meeting LO#3A.

Rubric for LO#3A

	(strongest) 10	8	6	4	2	(weakest) 0	Score
Organization	All moves are present, fully developed, and in the correct sequence. No extra moves are present.	All moves are present, but one move is out-of-sequence or has minor problems. No extra moves are present.	All moves are present, but a few have minor problems or are out of sequence. Extra moves may be present.	**One** move is missing or underdeveloped. Moves may be out of sequence; extra moves may be present.	**Two** moves are missing or underdeveloped. Moves may be out of sequence; extra moves may be present.	**Three** moves are missing or underdeveloped. Moves may be out of sequence; extra moves may be present.	
Audience & Conciseness	Wording is clear and concise. Level of detail, writing style, & formality are appropriate for an expert and/or scientific audience.	Wordiness and/or errors in level of detail, style, or formality occur in a handful **(2-3)** of instances.	Wordiness and/or errors in level of detail, style, or formality are noticeable **(4-5)**, and, at times, distracting.	Wordiness and/or errors in level of detail, style, or formality are frequent **(6-7)** and regularly distracting.	Wordiness and/or inappropriate level of detail, style, or formality are consistent **(8-9)** and seriously distracting.	Wordiness and/or inappropriate level of detail, style, or formality are common **(≥ 10)** and cause the reader to dismiss the work.	
Scientific Conventions, Grammar & Mechanics	Few **(1-2)**, if any, errors are made in scientific conventions, grammar, and/or mechanics.	A handful **(3-5)** of errors are made in scientific conventions, grammar, and/or mechanics.	Errors in scientific conventions, grammar, and/or mechanics are noticeable **(6-8)** and, at times, distracting.	Errors in scientific conventions, grammar, and/or mechanics are frequent **(9-10)** and regularly distracting.	Errors in scientific conventions, grammar, and/or mechanics are consistent **(11-12)** and make the writing appear unprofessional.	Errors in scientific conventions, grammar, and/or mechanics are common **(>12).** The writing is unprofessional.	
Science Content	Presentation of science is complete, correct, clear, and logical. Levelof science conveys an understanding that is sophisticated for course level.	Presentation of science is generally complete andcorrect, but **one** area is missing, problematic, or weakly developed.	Presentation of scienceis generally correct, but**two** areas are missing, problematic, or weakly developed.	Presentation of science contains several errors. **Three** areas are missing, problematic, or weakly developed.	Presentation of science isgenerally incorrect. **Four** areas are missing, problematic, or weakly developed.	Presentation of science conveys little scientific understanding. **Five** areas are missing, problematic, or weakly developed.	
Poster Aesthetics	Poster is (i) well laid out with appropriate font size and style. Poster has (ii) graphics, title and, schoollogo. Poster (iii) beckons and engages reader.		Poster has 2 out of 3 elements: Poster is (i) well laid out with appropriate font size and style. Poster has (ii) graphics, title and, schoollogo. Poster (iii) beckons and engages reader.		Poster has 1 out of 3 elements: Poster is (i) well laid out with appropriate font size and style. Poster has (ii) graphics, title and, schoollogo. Poster (iii) beckons and engages reader.	Poster has 0 out of 3 elements: Poster is (i) well laid out with appropriate font size and style. Poster has (ii) graphics, title and, schoollogo. Poster (iii) beckons and engages reader.	
	≥31 Points = Meets Expectations **<31 Points = Does Not Meet Expectations**					**Total Points**	

APPENDIX 3 - LO#3

The rubric for LO#3B is given below. Each facet of the learning outcome is scored. An average of 62% or above is considered meeting LO#3B.

Rubric for the LO#3B

	(strongest) 10	8	6	4	2	(weakest) 0	Score
Organization	All moves are present, fully developed, and in the correct sequence. Noextra moves are present.	All moves are present, but one move is out-of-sequence or has minorproblems. No extra moves are present.	All moves are present, but a few have minor problems or are out of sequence. Extra moves may be present.	**One** move is missing orunderdeveloped. Moves may be out of sequence; extra movesmay be present.	**Two** moves are missingor underdeveloped. Moves may be out of sequence; extra moves may be present.	**Three** moves are missingor underdeveloped. Moves may be out of sequence; extra movesmay be present.	
Audience & Conciseness	Wording is clear and concise. Level of detail, writing style, & formalityare appropriate for an expert and/or scientific audience.	Wordiness and/or errorsin level of detail, style, orformality occur in a handful **(2-3)** of instances.	Wordiness and/or errorsin level of detail, style, orformality are noticeable **(4-5)**, and, at times, distracting.	Wordiness and/or errorsin level of detail, style, orformality are frequent **(6-7)** and regularly distracting.	Wordiness and/or inappropriate level of detail, style, or formalityare consistent **(8-9)** andseriously distracting.	Wordiness and/or inappropriate level of detail, style, or formalityare common **(≥ 10)** andcause the reader to dismiss the work.	
Scientific Conventions	Few **(1-2)**, if any, errors are made in the use of scientific conventions.	A handful **(3-5)** of errorsare made in the use of scientific conventions.	Errors in scientific conventions are noticeable **(6-8)** and, at times, distracting.	Errors in scientific conventions are frequent**(9-10)** and regularly distracting.	Errors in scientific conventions are consistent **(11-12)** and make the writing appearunprofessional.	Errors in scientific conventions are common**(>12).** The writing is unprofessional.	
Grammar & Mechanics	Few **(1-2)**, if any, grammatical or mechanical errors are present.	A handful **(3-5)** of grammatical or mechanical errors are present.	Grammatical and mechanical errors are noticeable **(6-8)** and, at times, distracting.	Grammatical and mechanical errors arefrequent **(9-10)** and regularly distracting.	Grammatical and mechanical errors are consistent **(11-12)** and seriously distracting.	Grammatical and mechanical errors are common **(>12)** and limit the reader's ability to understand the material.	
Science Content	Presentation of science iscomplete, correct, clear, and logical. Level of science conveys an understanding that is sophisticated for course level.	Presentation of science isgenerally complete and correct, but **one** area is missing, problematic, or weakly developed.	Presentation of science isgenerally correct, but **two** areas are missing, problematic, or weakly developed.	Presentation of science contains several errors. **Three** areas are missing,problematic, or weakly developed.	Presentation of science isgenerally incorrect. **Four** areas are missing, problematic, or weakly developed.	Presentation of scienceconveys little scientific understanding. **Five** areas are missing, problematic, or weakly developed.	
≥31 Points = Meets Expectations **<31 Points = Does Not Meet Expectations**						**Total Points:**	

Appendix 3 - LO#3

Table A3.1 Percentage of students mastering LO#3A.

Academic Year	N	M	DNM	YA
2016-2017	21	18	3	86%
2017-2018	17	15	2	88%
2018-2019	18	16	2	89%
2019-2020	16	10	6	63%
2020-2021	5	2	3	40%
5YA:				66%

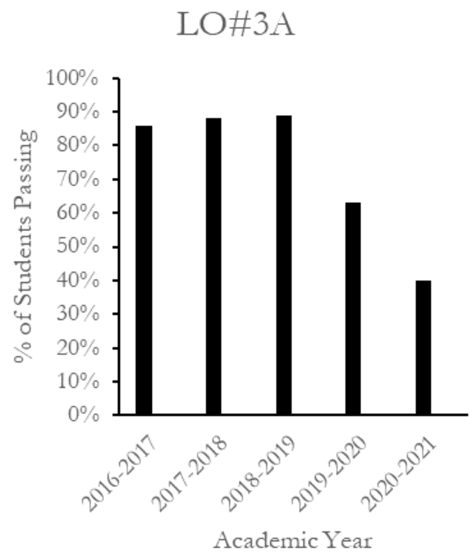
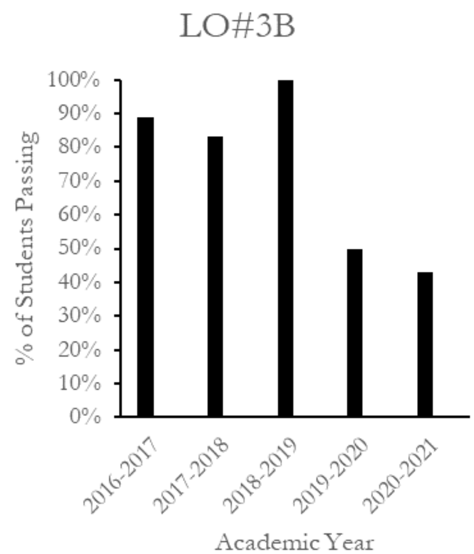


Table A3.2 Percentage of students mastering LO#3B.

Academic Year	N	M	DNM	YA
2016-2017	9	8	1	89%
2017-2018	12	10	2	83%
2018-2019	9	9	0	100%
2019-2020	2	1	1	50%
2020-2021	7	3	4	43%
5YA:				73%



N:	Number of students
Meets (M):	≥ 70% on rubric
Does Not Meet (DNM):	≤ 70% on rubric
YA:	yearly average of students meeting outcome
5YA:	five-year average of students meeting outcome