I. Summary of Assessment

A. Program Learning Outcomes

Program Learning Outcomes (PLO) for BS/BA Chemistry and BS/BA Biochemistry:

1. Demonstrate knowledge in the various areas of chemistry, including inorganic chemistry, analytical chemistry, organic chemistry, physical chemistry, and biochemistry (ILO 6).
2. Use quantitative reasoning to analyze and solve chemical/biochemical problems and evaluate chemical/biochemical data (ILO 1 & 6).
3. Work effectively and safely in a laboratory environment to perform experimental procedures and operate modern chemical/biochemical instruments (ILO 6).
4. Design, carry out, record and analyze the results of chemical/biochemical experiments (ILO 6).
5. Communicate chemical and biochemical issues clearly (ILO 2 & 6).

Program Learning Outcomes (PLO) for MS Chemistry:

1. Demonstrate mastery of specialized knowledge in the chemical sciences beyond the undergraduate level (ILO 6).
2. Work effectively and safely in a laboratory environment using chemistry laboratory techniques and chemical/biochemical instrumentation (ILO 6).
3. Use theoretical and experimental chemistry methods to test hypotheses or analyze and design solutions to problems (ILO 1 & 6).
4. Research, understand, organize, and critically assess information from the chemical literature (ILO 6).
5. Present complex chemical information via oral and written reports (ILO 2 & 6)

B. Program Learning Outcomes Assessed

BS/BA Programs: Based on our long-term curriculum assessment plan, the assessment focus of the academic year 2024-2025 is PLO 2. The data was collected from 4 classes: i) Chem 340 (Survey of Biochemistry) in Spring 2025, ii) Chem 352 (Physical Chemistry II) in Spring 2025, iii) Chem 442 (Biochemistry II) in Spring 2025, and iv) Chem 443 (Biochemistry Lab I) in Fall 2024.

Instrument: Submitted work and embedded questions in exams.
Sampling Procedure: All submitted work and exams.
Sampling Characteristics: Scores obtained for the exams.

Data Collection: The data was collected in Fall 2024 and Spring 2025.
Data Analysis: The submitted work was assessed for learning mastery by the instructor-in-charge.

MS Program: PLO 1 was assessed in the academic year 2024–2025. The data was collected from Chem 631 (Graduate Organic Chemistry) in Spring 2025.

Instrument: Submitted work and embedded exam questions.
Sampling Procedure: All submitted work and exam.
Sampling Characteristics: Scores obtained on the exam and final course grade.
Data Collection: The data was collected in Spring 2025.
Data Analysis: The submitted work was assessed for learning mastery by the instructor-in-charge.

C. Summary of Assessment Results

Main Findings

i. Chem 340 (Survey of Biochemistry)

Learning mastery was assessed based on the scores they received in the midterm and/or final exam.

Chem 340 SLOs

Students who successfully complete CHEM 340 will be able to:

1. Recall the structures of biomolecules.
2. Recall the structure and the composition of biological membranes.
3. Distinguish the different transport mechanisms across membranes.
4. Summarize enzyme kinetic and inhibition models.
5. Analyze kinetic data for enzyme-catalyzed reactions.
6. Explain the energetics of metabolic processes.
7. Outline the major catabolic and anabolic processes of biomolecules.
8. Formulate the relationship between structural or metabolic anomalies and diseases

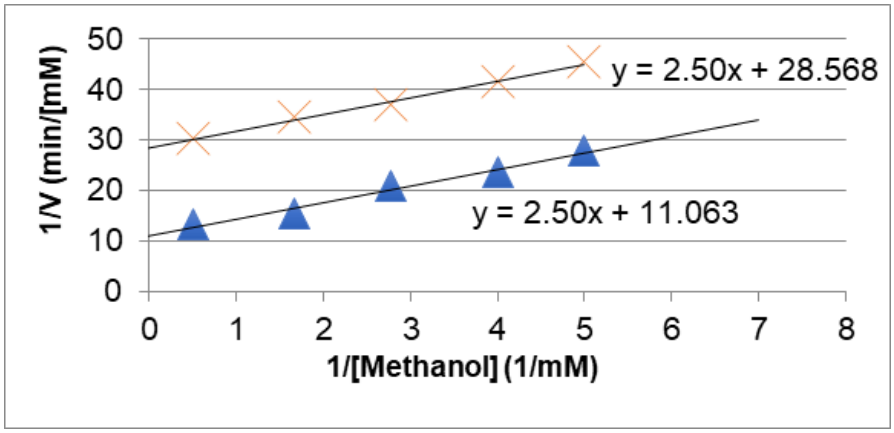
Assessment Design

Embedded questions in the midterm and final exam emphasize the use of quantitative reasoning to solve chemical/biochemical problems and evaluate chemical/biochemical data (PLO 2). Embedded questions also emphasize the ‘Thinking and Reasoning’ ILO and ‘Specialized Discipline’ ILO.
Shown below is a sample question from the midterm.

1. (18 pts) Recall the enzyme ADH (in your case study 2) that catalyzes the reaction of methanol to formaldehyde.

A. You decided to study this enzyme using an inhibitor molecule called ZZ.

Bottom line (triangle markers): conversion of methanol without ZZ.
Top line (x markers): conversion of methanol when ZZ is present.



i. How does ZZ affect K_M and V_{max}? Explain.

ii. Based on what we have learned from Worksheet 3, will ZZ be a competitive inhibitor for *ethanol* (careful: I am not asking about methanol, I am asking about ethanol). Explain briefly.

iii. Will ZZ be useful for preventing methanol poisoning? Explain.

Grading Criteria and Results

Students are considered to 'Meet' or 'Exceed' expectations if they scored 70% and above.
The result for Spring 2025 is as follows:

Major	# of students (% of students) that meet expectations
BA Chemistry	No BA Chemistry student in Spring 2025 Chem 340
BS Chemistry	3 out of 3 (100%)

Analysis

The assessment result from Chem 340 is highly encouraging as 100% of our BS Chemistry have met and/or exceeded expectations. The embedded question is reflective of mastery-level of the application of quantitative reasoning to chemical/biochemical problems that aligns with PLO 2 and the 'Thinking and Reasoning' ILO.

ii. Chem 352 – Physical Chemistry II

Chem 352 – Physical Chemistry II is a required course for students completing a BS in either Chemistry or Biochemistry. Because it is a key requirement in so many of our degree programs, we often use it for assessment purposes.

The final exam was used to assess student mastery of the learning objectives. The student learning objectives for the course were (as taken from the syllabus):

CHEM 352 SLOs

tudents who successfully complete Chem 352 should be able to:

1. describe the failures of classical physics that led to the formation of a quantum theory
    - including how classical models and quantum models predict differences in physical behavior
2. utilize the tools of Group theory to classify the geometry of a molecule
    - including applications in spectroscopy and molecular orbital theory
3. describe the quantum theory both qualitatively and quantitatively in terms of its fundamental postulates
4. employ quantum theory to describe the motions and observable properties of an atom or molecule in terms of vibrations, rotations, and electronic motions, as appropriate
5. analyze the results of spectroscopic measurements that probe molecular behavior

Assessment Design: Exam Questions

Exam questions tied to the Student Learning objectives have been used to gauge student mastery. These questions are taken from throughout the semester.

1. What is the kinetic energy (in eV) of a photoelectron produced from potassium ($\epsilon_{work} = 2.24\ eV$) using a laser tuned to 357 nm? (1 eV = 1.602E-19 J)
   K.E. = ___ eV

2. Consider the wavefunction given by $\psi(x) = A\,x \sin\left(\frac{\pi x}{a}\right)$, defined between x = 0 and x = a.

2. Plot the wave function.
3. Find a value of A that normalizes the wavefunction.
4. Find the expectation value of <x> for a system described by this wavefunction.

3. In the following Character table, Fill in the missing characters.

	E	2 A	3 B	C	2 D	3 F
A_1'	1	1	1	1	1	1
A_2'	1	1	-1	1	1	-1
E'	2		0	2	-1	0
A_1''	1	1	1		-1	-1
A_2''	1	1	-1	-1	-1	
E''		-1	0	-2	1	0

4. For $^{14}N^{16}O$, $\omega_e = 204\ cm^{-1}$.

   - From this value, calculate the force constant for the bond in the molecule.
     - Start by calculating the reduced mass. You may use the nominal isotopic masses for this problem.
   - Why is this force constant smaller than that for N_2?

These questions map to the SLOs according to the following table:

	SLO 1	SLO 2	SLO 3	SLO 4	SLO 5
Question 1	X				
Question 2			X	X	
Question 3		X			
Question 4					X

Grading Criteria and Results

Grades were assigned using a low-resolution grading scale that focused on mastery. The criterion for each score (1-4) are listed below:

Level of Performance		Criteria
1	Exceeds Expectations	Exercise is worked thoroughly, including a statement of applying a meaningful test of reasonableness, or some other critical evaluation of the solution.
2	Meets Expectations	Exercise is worked, but contains opportunities for improvement in communication in areas such as units, significant digits, clarity of assumptions, etc.
3	Needs Improvement	Exercise is completed, but contains significant errors, such as an incorrect answer, incorrect methodology, incorrect unit conversion, etc.
4	No Evidence of Mastery	Attempt provides no evidence that the student has a meaningful understanding of the problem or exercise.

A score of 0 was assigned if a student did not attempt a problem. A score of 3 is considered "sufficient". The number of students demonstrating each level of mastery is given in the table below:

	0	1	2	3	4
Question 1	1				14
Question 2	1	1	5	4	4
Question 3	1		5		9
Question 4	1		1	1	12

Analysis

These results are satisfying, overall. One student did not turn in any exams, and was assigned a grade of WU.

More than half of the class demonstrated satisfactory mastery on each the questions, with the poorest performance coming on Question 2. On this particular problem, the bulk of students who did not achieve mastery has mis-read the wavefunction, solving the problem instead for the function $\psi(x) = A \sin\left(\frac{\pi x}{a}\right)$, dropping the factor of x. While a number of students chose to re-work the problem once this error was explained, several chose to not rework the problem, which is disappointing.

The best performance was for the photoelectric effect problem (Question 1), which also involved the most rudimentary mathematics (i.e. No calculus.)

Overall, I feel confident that the class is mastering the learning objectives. This is the second semester I have used the low-resolution grading mechanism in this course, and am satisfied that the paradigm is serving these upper-division students well. It will be interesting to see if this trend continues into year 3 of the experiment.

iii. Chem 442 (Biochemistry II)

Learning mastery was assessed based on students' answers to embedded questions on two midterm exams.

Chem 442 SLOs:

Upon successful completion of CHEM 442 students will be able to:

1. Explain the basic principles of bioenergetics and analyze the standard and actual free energy changes of biochemical reactions.
2. Outline key cellular metabolic processes.
3. Discuss the importance of metabolic regulatory mechanisms.
4. Summarize the structural details of nucleic acids and nucleotides.
5. Illustrate the enzymatic processes of DNA replication, repair, and recombination.
6. Explain the processes that control RNA synthesis and maturation.
7. Explain the translation of mRNA into functioning proteins by ribosomes and tRNA.

Assessment Design

Embedded questions in the midterm exams emphasize the application of quantitative reasoning to solve chemical/biochemical problems and evaluate chemical/biochemical data (PLO 2). Embedded questions also emphasize the 'Thinking and Reasoning' ILO and 'Specialized Discipline' ILO. Representative exam questions from Midterm #1 are shown below.

Question 2 (4 Points): Calculation - Provided: R = 8.314 J/(K mol)
The standard free energy of hydrolysis for acetyl phosphate is $\Delta G^{0'} = -42.3$ kJ/mol. Calculate the free energy change ΔG for acetyl phosphate hydrolysis in a solution of 2 mM acetate, 2 mM phosphate, and 0.003 mM acetyl phosphate at a temperature of 300 K.

Question 9 (6 points):

List the four steps of glycogen synthesis. Include the names of the enzymes that are involved in each of the steps.

Question 11 (6 points):

Identify the pathway in which the enzyme participates in and identify whether the listed allosteric effector molecule is an inhibitor or activator of the enzyme.

Name of enzyme	*Pathway*	*Allosteric effector*	*select:* ***inhibits*** *or* ***activates***
Phosphofructokinase		ATP	
		AMP	
Fructose-1,6-bisphosphatase		AMP	
Glycogen phosphorylase		ATP	
		AMP	
Pyruvate carboxylase		Acetyl-CoA	
Pyruvate kinase		Acetyl-CoA	
Glucose-6-phosphate dehydrogenase		NADPH	

Briefly explain how you made your decisions on the allosteric inhibitor type:

Grading Criteria and Results

Students are considered to 'Meet' or 'Exceed' expectations if they scored 70% and above on the two exams.

Major	# Students (% of students) that Meet or Exceed Expectations
BA Biochemistry	No BA Biochemistry students in Spring 2025 Chem 442
BS Biochemistry	Midterm 1: 6 of 8 (75%) Midterm 2: 8 of 8 (100%)

Analysis

The assessment result from Chem 442 is encouraging. The majority of BC Biochemistry students (75%) met and/or exceeded expectations for Midterm 1, and 100% of the BS Biochemistry students have met and/or exceeded expectations for Midterm 2. This increase shows students ability to meet learning objectives improves over the course of the semester. The embedded questions are reflective of mastery-level of using quantitative reasoning to analyze biochemistry problems (PLO 2) and aligns strongly with the 'Thinking and Reasoning' ILO and the 'Specialized Discipline' ILO.

IV. Chem 443 (Biochemistry Lab I)

Learning mastery was assessed based on students' answers to embedded questions on a final exam.

Chem 443 SLOs: Upon successful completion of this course students will be able to:

1. Apply buffer theory and prepare a laboratory buffer.
2. Conduct protein and enzyme activity assays and calculate results from laboratory-derived data.
3. Collect and analyze enzyme kinetic data and present this data in graphical format.
4. Calculate and interpret data commonly found in protein purification tables.
5. Summarize the principles of various chromatographic methods and outline the practical procedures.
6. Explain the theory of protein electrophoresis and utilize this technique in laboratory experimentation.
7. Develop and maintain an informative and up-to-date laboratory notebook and compose well-written laboratory reports.

Assessment Design

Embedded questions in the midterm exams emphasize the use of quantitative reasoning to solve chemical/biochemical problems and evaluate chemical/biochemical data (PLO 2). Embedded questions also emphasize the 'Thinking and Reasoning' ILO and 'Specialized Discipline' ILO.

Question 3 (4 points):

In the laboratory you have the following three chemical compounds:

a.) 2-(N-Morpholino)ethanesulfonic acid (pKa=6.15), also called MES
b.) Tris(hydroxymethyl)aminomethane (pKa=8.30), also called Tris
c.) Acetic acid (pKa=4.74)

Which of these three compounds should you choose to make an effective buffer with a pH value of pH=6.0?
Explain your choice:

Question 7 (10 points):

A student performed an activity assay by mixing 0.4 mL of 100 mM dopamine with 0.50 mL of 100 mM sodium phosphate buffer, pH 6.6, 0.08 mL distilled water, and 0.02 mL plant extract in a cuvette. She obtained an absorbance decrease of 0.2 in one minute while setting the spectrophotometer to a fixed wavelength of 480 nm. The molar absorptivity of the assay product at 480 nm is 3,300 M^{-1} cm^{-1}.

a.) Show the chemical reaction on which this assay is based. Briefly explain the principle of the assay.

b.) What is the total volume of the reaction mixture in the cuvette?

c.) What is the concentration of dopamine in the assay after adding all other components?

d.) Convert the PPO activity from Abs/min into International Units (IU).

Question 11 (8 points):

The table below contains literture data on the inhibition of PPO from mushroom with cinnamic acid and 4-hydroxycinnamic acid.

	IC_{50} (mM)	Inhibition type

Cinnamic acid	2.10	Non-competitive
4-Hydroxycinnamic acid	0.50	Competitive

a.) Write out a definition for $IC_{50.}$

b.) Based on the IC_{50} values, which molecule is the more potent inhibitor: cinnamic acid or 4-hydroxycinnamic acid?

c.) The inhibitor type was determined for both inhibitors using Lineweaver-Burk plots. Sketch out the Lineweaver-Burk plots for both cases.

d.) Which enzyme-form (free enzyme or enzyme-substrate complex) does 4-hydroxycinnamic acid bind to?

Grading Criteria and Results

Students are considered to 'Meet' or 'Exceed' expectations if they scored 70% and above.

Major	# Students (% of students) that Meet or Exceed Expectations
BA Biochemistry	No BA Biochemistry students in Fall 2024 Chem 443
BS Biochemistry	7 of 7 (100%)

Analysis

The assessment result from Chem 443 is very positive, where 100% of the BS Biochemistry students have met and/or exceeded expectations on the course final exam. The embedded questions are reflective of how students obtain mastery of using quantitative reasoning to analyze biochemistry problems (PLO 2). This PLO aligns strongly with the 'Thinking and Reasoning' ILO and the 'Specialized Discipline' ILO, as students have successfully obtained the appropriate knowledge and skillset to successfully evaluate biochemical data through quantitative means.

V. Chem 631 (Graduate Organic Chemistry)

Learning mastery was assessed based on students assigned final grade.

Chem 631 SLOs

Students who successfully complete Chem 631 should be able to:

1. Predict the geometric structure, reactivity and other properties of organic molecules.
2. Predict the conformational preference of organic molecules and the stereochemical preference in reactions.
3. Describe different types of reactive intermediates and their importance in reactions.
4. Evaluate and apply different techniques for the determination of mechanisms of organic reactions.
5. Predict products or design syntheses of carbon-carbon bond formation reactions.
6. Determine structure of organic molecules through use of IR, NMR, and mass spectrometry.

Assignment Objective and Design

Embedded questions in the exams and weekly assignments exhibit expertise in a specialized discipline beyond the undergraduate level. The assignments exam questions required students to construct organic reaction mechanisms for a reaction they have not seen before. To successfully come up with the mechanisms reflects mastery of the fundamental and critical concepts in organic chemistry, understanding of molecule behavior, and integration of ideas and theories.

Grading Criteria

Students are considered to 'Meet' or 'Exceed' expectations if they received a final grade of "B" or better in the course. Graduate students are required to maintain a 3.0 grade point average in order to maintain good academic standing.

Major	# of students (% of students) that Meet or Exceed Expectations
MS Chemistry	15 of 18 (83%)

Analysis

The assessment result from Chem 631 is positive. The majority of MS Chemistry students (835) met and/or exceeded expectations for the course. This result demonstrates that the majority of students are mastering specialized knowledge in chemistry beyond the undergraduate level (PLO 1). This result aligns strongly with the 'Specialized Discipline' ILO.

Analysis of BA/BS programs:

The assessment results for both Chem 340, Chem 352, Chem 442, and Chem 443 are satisfactory. For Chem 340, all 3 BS Chemistry students met the learning objectives. For Chem 352, the majority of students are mastering the material on the embedded questions on the exam assessment. Chem 352 is a historically challenging course, so this is a very positive result. For the 8 BS Biochemistry students in Chem 442, there were improvements in exam performance over the course of the semester, where 75% meet/exceed expectations on midterm 1, 100% meet/exceed expectations on midterm 2. This demonstrates students' growth and mastery of the course learning objectives during the semester. For Chem 443, all 7 BS Biochemistry students meet/exceed expectations on the final exam.
We were not able to assess BA Chemistry or BA Biochemistry students in the 2024-2025 academic year due to no majors being enrolled in the courses assessed.

Analysis of MS program:

Overall, a majority of MS Chemistry students (15 of 18, or 83%) met or exceeded expectations through completion of embedded questions on exams and weekly assignments as reflected in their final grade. This is encouraging, and shows MS Chemistry students' ability to master specialized knowledge beyond the undergraduate level.

Reflections, Recommendation for Program Improvements, and Next Step for Closing the Loop:

The majority of BA/BS and MS student work assessed met the learning outcomes. None of the students assessed had failing grades (D/F) or received a WU, which is highly encouraging. However, in the undergraduate courses, some students did not perform as well as we had hoped, such as on the first midterm exam in Chem 442. At that point in the course, students may have not had a high degree of mastery with the material or did not have sufficient time to review the material for the exam. In the MS Chemistry course assessed, 3 of 18 students did not meet expectations based on their final grade but did earn a final grade that is considered passing in the course (C/C+/B-). This result is encouraging, because it shows that all students have the potential to meet or exceed expectations in the course in the future.

Based on the overall assessment, we recommend some strategies in the future to improve course outcomes. First, we recommend that instructors incorporate a higher frequency of formative assessments. This will encourage students to keep up with the pace of the material throughout the semester, and it also allows for faculty to assess student mastery in real time. We recommend formative assessments should be graded based on completion instead of accuracy to encourage students to complete the work, even if it may not be totally accurate. Second, we recommend that instructors explore giving students the opportunity to complete exam revisions with a self-reflection component, potentially giving back partial credit. This will help students reflect on their mistakes, earn credit for their efforts, and strategize on how to improve mastery as the semester progresses.

D. Assessment Plan for Next Year (AY 2025-2026)

The BA/BS assessment plan for the academic year 2025–2026 is PLO 3 which aligns with ILO 6 (Specialized Discipline). For the MS program, we will assess PLO 2 in academic year 2025-2026 which aligns with ILO 6.