

Assessment Report for the Department of Chemistry
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1. Summary

The Chemistry Department has been actively engaged in reforming our 4-year undergraduate chemistry degree programs for the last several years. In 2014, we were awarded an HHMI grant to achieve this goal. Since that time, we have designed entirely new foundational courses for years 1 and 2 of the chemistry major and many new electives for the advanced level. We administered pilot sections of the first two foundational courses (Chem 150 and 202) during the 2016-2017 academic year. The first full implementation for first-year students started in the fall of 2017.

The goal of this report is to outline the steps the Chemistry Department has taken to ensure ongoing and active assessment of its reform efforts that will lead to measurable outcomes and successive improvement of the curriculum in the years ahead. Each of the following sections outline the goals we have defined in three different areas – programmatic goals, course goals, and attitudinal effects. We have designed our assessment plan to include pre- and post-reform data and to address all three areas using a variety of quantitative and qualitative assessment tools.

- A. Programmatic Goals (PG)
- B. Individual Course Goals (ICG)
- C. Attitudinal Effects (AE)

A. Programmatic Goals (PG)

In order to approach assessment of our curriculum redesign, we first needed a clear vision of what outcomes we desired and how we were going to achieve them. We began with a detailed articulation of programmatic goals for chemistry majors.¹

PG1. Majors will be prepared to begin careers or continue their education in variety of field. These could be, but are not limited to:

- Graduate work in chemistry, biochemistry, and related fields. Students with an Emory chemistry degree will be highly prepared to succeed in related graduate fields.
- Careers in industry, government, academia and research.
- Continuing education in all medical, dental, and veterinary fields. The chemistry degree provides a very strong background and basis set on which to continue these specialized fields of study.
- Other career paths that build on the knowledge and skills of the major. These might include law, engineering, primary or secondary education, or government work.

¹ Adapted from Trinity College, Duke University. Used with permission.

PG2. Majors will develop a comprehensive knowledge base in chemistry and molecular science. The chemistry curriculum should include foundational and in-depth courses that span the traditional sub-disciplines of chemistry, that integrate concepts across these sub-disciplines, and that illustrate how molecular thinking can be applied to other basic and applied science disciplines such as biology and engineering. Majors will have the ability to apply formal knowledge to real chemical and materials problems. Course assignments should help students develop critical thinking and problem solving skills, and should demonstrate the similarities and differences in how these skills apply in different areas of chemistry. Independent research projects should deepen this knowledge and illustrate its application to solving complex problems. The detailed selection of courses, topics, and requirements should conform to the guidelines of the ACS.

PG3. Majors will develop skills in laboratory and computational chemistry, including proper laboratory safety procedures. Students should be able to interpret and evaluate their results critically and to identify and quantify uncertainties in their measurements and limitations in the methodologies they employ. According to the ACS guidelines, “the laboratory experience must include synthesis of molecules, measurement of chemical properties and phenomenon, hands-on experience with modern instrumentation, and computational data analysis and modeling.” Students should also learn laboratory safety skills, including the proper handling and disposal of chemicals, the use of material safety data sheets and compliance with safety regulations, and an understanding and awareness of potential chemical and physical hazards in the laboratory.

PG4. Majors will develop effective oral and written communication skills. Opportunities for developing communication skills should be available both in lecture and laboratory courses, as well as in independent study research, and should incorporate critical evaluation and review by both experts and peers. Service as a peer tutor or laboratory assistant provides another opportunity for growth in these areas, as do meetings with research groups or visiting scientists. Development of communication skills should be a guided and staged process as students progress through the major, with later experiences reinforcing and expanding on earlier ones. Per the ACS guidelines: “Students should be able to present information in a clear and organized manner, write well-organized and concise reports in a scientifically appropriate style, and use appropriate technology such as poster preparations software, word-processing, chemical structure drawing programs, and computerized presentations in their communication.”

PG5. Majors will become adept at searching, accessing, retrieving, and critically evaluating information from the scientific literature. Students should learn to discern among competing claims, and be able to propose new studies that can discriminate between them. More generally, as students progress and mature they should become increasingly independent learners, moving beyond textbooks and courses and into learning directly from the primary

literature, especially within the context of independent research. Students should also learn the proper methods for citing the work of others in written reports and oral communications.

PG6. Majors will be able to use the scientific method and critical thinking to solve chemical problems. Majors should develop the ability to design and carry out experimental, computational, and/or theoretical studies aimed at solving problems in molecular science. In doing so, students should learn how to formulate testable hypotheses, how to analyze and interpret their results objectively, and how to make scientifically defensible choices among alternative explanations. Such skills should be developed in a progressive process that builds through lecture and laboratory courses and into independent research.

PG7. Majors will develop the ability to collaborate effectively as part of a team working together to solve problems, to engage in scientific debates, to value different points of view, and to interact productively with a diverse group of team members. Such skills are essential for working in the multidisciplinary teams that are increasingly required for tackling complex, interdisciplinary problems. The chemistry curriculum should promote teamwork skills through group problem solving exercises in lecture classes, through group projects in laboratories, through peer review exercises, through independent study projects, and through other forums such as service learning and outreach efforts.

PG8. Majors will develop an understanding of the ethical and societal dimensions of science and chemistry, and will learn and put into practice the expectations for responsible conduct. This understanding should extend from more narrowly focused issues in chemistry, such as those associated with safety, properly crediting the work of others, or the falsification of data, to more general ones involving the place of chemistry in contemporary society and global issues. Students should develop an appreciation of the expectations for professional behavior in science, especially the idea that solving complex problems is a participatory process that usually requires collegiality and sharing of ideas among many different people. These issues should be incorporated throughout the curriculum, but can be especially meaningful within the context of independent research. Chemistry outreach and service learning provide another opportunity for developing a sense of teamwork and civic responsibility.

B. Individual Course Goals (ICG)

The faculty in the Chemistry Department have collaborated to design course goals for each new foundational course in the major. These course goals are meant to combine scientific practices and skills with overarching content knowledge that connects to the big ideas of chemistry. As an example, the course goals for Chem 150 are included below, which summarize a more detailed granular level of class-by-class learning objectives (see Appendix I).

- Students will use their understanding of electrostatics and Coulomb's Law to predict changes in potential energy for a given atomic/molecular system.

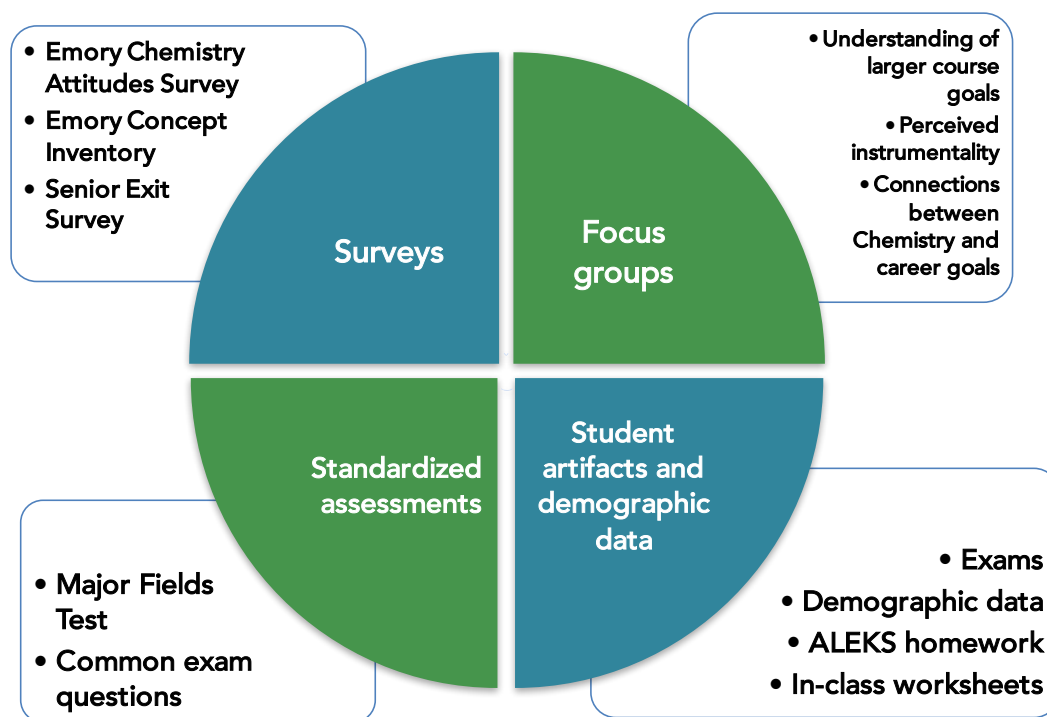
- Students will use their understanding of potential energy to predict and explain measurable physical properties like bond energy, lattice energy, rotational energies, and intermolecular interactions.
- Students will recognize, construct and use atomic models to make predictions about atomic and periodic properties
- Students will be able to do mathematical calculations to propose, support, or refute claims about chemical phenomena.
- Students will be able to interpret scientific data presented in mathematical and graphical form.
- Students will be able to write scientific explanations that consistently include claim, evidence, and reasoning.
- Students will be able to recognize, construct, and use 3-D representations to make predictions about physical properties (polarity, melting point/boiling point, and chirality)
- Students will be able to convert a 3-D representation to a 2-D representation

C. Attitudinal Effects (AE)

Students come to college with a diverse background in their exposure to and appreciation for science. Social science research reveals that as students proceed through STEM fields, many lose interest and leave the area of study. This is exacerbated for underrepresented groups. Additionally, the public image of science is too often one of misunderstanding or fear. One of our reform goals is to improve students' attitudes about science by designing a curriculum that builds societal impact and real-world applications into the fabric of the courses. We have also prioritized blending the sub-disciplines of chemistry across the five foundational courses, so students see engaging and practical examples of biology, physics, geology, medicine, materials, etc. earlier in their college careers.

2. Overview of Assessment Plan

By using standardized assessments, collecting student artifacts, conducting focus groups, and administering surveys, we have been able to collect data (and are continuing to collect data) corresponding to each of the three major outcome areas. In the 2016-2017 academic year, the department piloted two sections of the new Chemistry 150 course as well as the subsequent 202 course (under two sections of the traditional 141/142 sequence). These pilot courses ran concurrently with traditional sections of Chem 141 and 142 (first and second-semester general chemistry). This provided us with a unique assessment opportunity that has contributed to the overall data collecting and larger assessment plan outlined below. Though we have a limited amount of assessment data collected so far, the assessment plan moving forward is thoroughly outlined below. We have codified each assessment tool according to its target outcome area.



A. Surveys

Emory Chemistry Attitudes Survey (PG1, PG3, PG4, PG7, PG8, AE)

In order to explore specific aspects of the new curriculum in greater detail, the department of chemistry has contracted external evaluation experts from Georgia Tech. We are partnering with the Georgia Tech team to analyze results from the Emory Chemistry Attitudes Survey, an in-house survey designed to collect students' self-reported attitudes towards science in general and, more specifically, chemistry and chemistry research. A copy of the survey can be found in the

Appendix II. The chemistry department has collected this survey for the past two years from students at the beginning and end of the year-long general chemistry sequence. The Georgia Tech team is in the initial phase of data analysis and we expect to discuss preliminary results from the past two years in October of 2017. Over the course of this academic year, we will continue to partner with them to analyze this data in greater detail, make edits to the survey design and administration as needed, and gather additional data through student interviews to develop a well-rounded picture of how student attitudes towards chemistry change as they progress through offered coursework. The chemistry department also intends to continue giving this survey as the new curriculum is fully implemented to determine the impact of the new curriculum on students' attitudes towards science.

Emory Concept Inventory (PG2, PG6, ICG)

Our curricular design particularly emphasizes overarching course goals and themes. In order to convey these larger goals, class by class learning objectives were designed for each foundational course. With a renewed focus on course goals, the Emory assessment team within the chemistry department has designed an in-house concept inventory meant to assess students understanding of larger chemistry concepts rather than specific chemical facts or skills. Through collecting faculty feedback, student interviews, and pilot testing, the Emory assessment team has designed a preliminary survey meant to cover major concepts taught in the first four foundational courses of the new curriculum. In the fall of 2017, the assessment team will continue to revise the survey items as needed and produce a finalized copy of the survey to administer at the end of the 2018 spring semester to students currently enrolled in Chem 222 (second-semester organic chemistry). This group of students will be part of the last year of traditional organic chemistry to be offered at Emory and will provide a pre-reform data set of student understanding of these larger chemistry concepts. The department will then continue to administer the Emory Concept Inventory at three time points across a given students' academic stay at Emory: at the beginning of their first chemistry course, upon their completion of the first four foundational courses, and at the end of their senior year (this last time point will only apply to chemistry majors). A copy of the inventory can be found in the Appendix III.

Senior Exit Survey (AE, ICG, PG3, PG4, PG5, PG7)

The chemistry department has administered a senior exit survey to all graduating seniors for the past seven years. The survey is intended to collect background information about the courses and experiences that chemistry majors engaged in during their time at Emory, their proficiency and confidence in performing standard chemistry skills and practices, and general feedback on their educational experience and suggestions for improvement for the department. In the spring of 2017, we added several questions that more clearly align with our programmatic goals. A copy of the survey can be found in the Appendix IV.

B. Standardized Assessments

Major Fields Test (ICG, PG2, PG6)

The chemistry department is currently exploring the use of the Major Fields Test (MFT) in chemistry, designed and administered by ETS, as an exit exam for chemistry majors graduating from our department. The Chemistry MFT consists of 100 multiple choice questions and is designed to be a comprehensive undergraduate chemistry assessment (<https://www.ets.org/mft/about/content/chemistry>). The purpose of the MFT will be to determine Emory student performance on a range of chemistry topics that we will expect them to have mastered by the end of their chemistry coursework as well as to compare them to nationwide data collected by ETS. Emory will administer the first Chemistry MFT to graduating seniors in the spring of 2018. This will provide us with pre-reform data from students who have participated in the traditional chemistry curriculum at Emory. The department will continue to administer the Chemistry MFT to graduating seniors as the new curriculum is introduced to determine the impact of the new coursework on students understanding of traditional chemistry content.

Common Exam Questions (ICG, PG2, PG4)

The chemistry department has begun to introduce common exam questions on mid-term and final exams in its foundational courses (general chemistry, organic chemistry, and the new pilot courses). To determine the impact the new pilot courses had on student understanding of specific learning objectives, we gave common multiple-choice and short answer exam questions across foundational chemistry sections. For Chem 150, we gave five questions to our pilot students as well as to students in the traditional Chem 141 sections (first-semester general chemistry). The specific questions are provided in the (Appendix V), along with the learning objectives they were meant to assess. The percent of correct responses for each group of students are shown below in Table 1. For all five questions, the data show that the students in the pilot did as well or better than the traditional students. Three of the five questions were meant to test their mathematical skills, a skill that the 150 pilot course chose to off-load to the ALEKS on-line homework system in favor of spending more class time on deeper conceptual problems. The remaining two multiple-choice questions were meant to probe student understanding of specific concepts, ones that are often reported in the chemistry education literature as a source of misconceptions.

Course	Correct Responses (%)				
	Question 1	Question 2	Question 3	Question 4	Question 5
Chem 141 Group A (N=173)	94	72	98	66	79
Chem 141 Group B (N=84)	85	76	94	60	85
Chem 150 Pilot (N=176)	90	74	90	70	87

Table 1: Percentage of correct responses to questions administered to Pilot Chem 150 students and traditional Chem 141 students

We also gave two open-ended questions to the pilot 150 students and to students enrolled in a traditional Chem 221 course (first-semester organic chemistry). Again, the specific questions are provided in Appendix V, along with the learning objective they were meant to assess. The percent of correct responses for each group of students are shown below in Table 2. In general, the pilot students did not perform as well as the traditional Chem 221 students on these items. We should note, however, that these same two items have been included on the Emory Concept Inventory and our initial data collection from students who have completed a full year of traditional organic chemistry show performances similar to the Chem 150 pilot students.

Course	Correct Responses (%)	
	Question 1	Question 2
Chem 221 Group A (N=187)	82	92
Chem 150 Pilot (N=178)	57	68

Table 2: Percentage of correct responses to questions administered to Pilot Chem 150 students and traditional Chem 221 students

The department also gave common exam questions for students enrolled in the Chem 202 pilot course in the spring of 2017 as well as to their peers in the traditional Chem 142 course and Chem 222 course (second-semester general chemistry and second-semester organic chemistry respectively). These questions have not yet been analyzed. As fall 2017 marks the beginning of the new curriculum with all first-year chemistry students taking the Chem 150, the department is continuing to write and administer common exam questions to all Chem 150 mid-term and final exams to determine students' understanding of specific learning objectives highlighted by the new curriculum as well as the homogeneity of instruction. The department plans to continue this practice as the subsequent new courses are introduced.

It is worth noting that the department has also begun to collect student data via artifacts (predominantly exam items) to determine the impact of the new curriculum on students' ability to carry out three scientific practices: developing a scientific explanation, interpreting and explaining scientific data, and three-dimensional visualization. These three practices are emphasized heavily in the first two new foundational courses and specific assessment items meant to integrate these practices with core chemistry content are currently being written and administered in the new Chem 150 course.

C. Student artifacts and demographic data

Student artifacts (PG2, PG3, PG4, PG7, ICG)

The department, with IRB approval, has collected a wide variety of student artifacts over the past year to paint a picture of a typical class day in the new and old curricula. These artifacts include lecture slides, in-class worksheets, clicker questions, and descriptions of in-class demonstrations provided by course instructors. The artifacts also include copies of students' exam responses for first-year chemistry courses, student performance on the ECCP (Emory College Chemistry Prep) and student homework data, the last two being collected via the ALEKS online homework system. These artifacts will be available to the Emory assessment team for further exploration to help categorize pedagogical methods used by instructors, determine how course content is delivered to students, to classify students' understanding of chemistry content based on previous high school instruction, and to analyze student understanding of specific learning objectives as assessed through mid-term and final exams.

Demographic data (PG1)

The department, with assistance from the Office of Institutional Research, is currently collecting a wide range of demographic data for students enrolled in our chemistry courses as well as those that go on to declare a chemistry major. Demographic data of interest includes: sex, age, race, SAT/ACT scores, and GPA as well as student grades in specific chemistry courses and DWF rates. The department is also working to collect post-graduate information from students who graduate with a chemistry major including graduation rates and career/education paths. With this information, the Emory assessment team will be able to track student success in chemistry (specifically for underrepresented groups), identify when students leave chemistry (or the sciences in general), and determine the department's impact on students' future career paths. With the help of the Georgia Tech assessment experts, the department then plans to follow up with students who have left the sciences as well as those who have declared chemistry as their major to discuss their experiences and the impacts of those experiences through targeted interviews and focus groups.

D. Focus Groups

Understanding of larger course goals (PG2, PG4, PG6, ICG)

The Emory assessment team will begin to develop an interview protocol this semester to explore students' understanding of the overarching chemistry themes for the foundational courses as well as their ability to engage in three scientific practices of interest: developing a scientific explanation, interpreting and explaining scientific data, and three-dimensional visualization. Interviews will be conducted with students in both the new and the old curriculum in the spring of 2018. The team hopes to use this interview data to supplement the Emory Concept Inventory and the common exam questions to describe differences in student understanding as a result of the new curriculum.

Perceived Instrumentality and Connections (PG1, PG8, AE)

The team of assessment experts at Georgia Tech have proposed a series of interviews and focus groups with students to explore, in depth, specific assessment items found on the Emory Chemistry Attitudes Survey. The Georgia Tech team will develop a protocol, using Future Time Perspective (FTP) theory as a theoretical framework, to answer two main questions:

1. To what extent do Emory students connect their experiences in Chemistry courses to their future academic or career interests?
2. To what extent do Emory students believe that what they are learning in their Chemistry courses will be useful for advanced coursework and/or success in their chosen careers?

In conjunction with specific survey items that pertain to these topics, the Georgia Tech team will analyze their findings to describe how students are thinking about their experience in the Chemistry program here at Emory in relation to their future goals and career objectives.

Additional Reform Goals (PG2, PG8, ICG, AE)

The team will also begin to draft interview protocols for the following research interests identified by the department:

1. Students' perception of choice within the major:
 - a. How they feel about the amount of choice (or lack thereof) they currently have.
 - b. What courses would they like to see that might better align with their interests and career goals.
2. If and how students are making connections between the chemistry they learn in the classroom and the "real world".
3. If and how students are able to identify and describe connections between the chemistry courses they have taken.
4. Faculty perceptions of the new curriculum content and design, the development process, and any perceived losses or gains as a result of the new curriculum.
5. Experiences of faculty in charge of teaching the new curriculum for the first time.

A more detailed description of each of these research interests is provided in Appendix VI.

Faculty Response and Adaptation

Finally, the Chemistry Department plans to discuss the results of these assessments in an annual faculty-wide discussion at a time to be determined by the chair and the assessment committee. At this time the faculty will propose further pedagogical and curricular evolution based on the results. We hope that over time, this will develop a strong culture of assessment within the department.