Millikin University
Student Learning in the Chemistry Major

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Executive Summary

The Department of Chemistry supports the mission of the university in preparing students for professional success, democratic citizenship in a global community, and a personal life of meaning and value by producing graduates who achieve the following three chemistry-specific learning outcome goals:

1. Demonstrate the skills to solve problems and communicate through writing and speaking.
2. Discover how to integrate and apply knowledge and skills both within the chemistry community and between chemistry and other disciplinary communities.
3. Develop the capacity to address real-world scenarios in which chemistry plays a role.

Our curriculum introduces each student to the five sub-fields of chemistry recommended by the Committee on Professional Training of the American Chemical Society. These are: inorganic, organic, physical, analytical, and biochemistry. We have one faculty member for each of these sub-fields. The Chemistry curriculum incorporates the integration of theory and practice. Theory is emphasized in classroom activities while practice is emphasized in the laboratory. In some cases, courses tightly integrate the two. Every chemistry major completes a core curriculum. Depending upon their individual interests, students then select additional study in one of four areas that we call emphases: research, secondary education, biochemistry, or business.

Regardless of emphasis, undergraduate research is the capstone of the chemistry major at Millikin. This activity requires the synthesis of all three learning outcome goals and therefore is the easiest to assess uniformly. Undergraduate research has four components: the proposal, the research, a final written report, and a final oral presentation. Research requires significant creative work. Excellent undergraduate research characterizes excellent chemistry programs nationwide.

We created a rubric for assessing each component of undergraduate research: proposal, performance, and presentation. Based on the rubrics we created for assessing the proposal, performance, and presentation of research, we rate our current status on all three learning goals as "green light" (at an acceptable level). We will continue to work on ways to ensure that all our students perform at the "green light" level in the future.

Report

Goals

The Department of Chemistry supports the mission of the university in preparing students for professional success, democratic citizenship in a global community, and a personal life of meaning and value. The mission of the department is to produce graduates who achieve the following three learning outcome goals:

1. Demonstrate the skills to solve problems and communicate through writing and speaking.
2. Discover how to integrate and apply knowledge and skills both within the chemistry community and between chemistry and other disciplinary communities.
3. Develop the capacity to address real-world scenarios in which chemistry plays a role.

The successful graduate of the Department of Chemistry is not necessarily a professional chemist. For example, recent graduates are working in the chemical and pharmaceutical industry, practicing medicine or pharmacy, selling technical goods and services, running their own businesses, teaching, and working in the areas of government and law, among other things.

Snapshot

The Department of Chemistry is approved by the Committee on Professional Training (CPT) of the American Chemical Society (ACS). The department consists of five full-time faculty members representing the five major sub-fields of chemistry: analytical chemistry, biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. All chemistry majors choose one of four emphases: biochemistry, business, research, or secondary education. Students complete 23 credits of common core courses plus additional courses specific to the emphasis. Our CH121-General Chemistry course serves approximately 200 students per year, including students majoring in chemistry, biology, nursing, elementary education, athletic training, physical education, psychology, and exploratory studies, *inter alia*. Our CH224-Inorganic Chemistry and CH301/302-Organic Chemistry courses each serve approximately 50-65 students per year, primarily chemistry and biology majors. In the decade from 1994 to 2004, approximately nine majors per year graduated with chemistry degrees. Since 2004, the number of majors has typically been above that number--as high as 18 in 2008--in part due to our new science center. Slightly fewer than half of our graduates pursue advanced degrees.

The Department of Chemistry resides in the 83,000-square-foot Leighty-Tabor Science Center, which opened in the spring 2002 semester. We also joined Midwestern University in a dual-acceptance pre-pharmacy agreement. In terms of curriculum, our most recent initiatives have been in course delivery, specifically the Block CH121, designed for students with limited chemistry backgrounds, that meets five days a week for half the semester. The block concept was extended to our CH203/205—Essentials of Organic and Biochemistry service course during the spring 2005 semester. Beginning

with the fall 2005 semester, we instituted a math proficiency requirement for CH121 enrollment. Beginning in 2008, ACS-CPT modified the curricular requirements necessary for program approval. A review of our curriculum indicates that our current curriculum meets the modified ACS-CPT requirements. Also in 2008, working in cooperation with the staff of Staley Library, we added two new resources for students to use in research: ACS Web Editions and SciFinder Scholar. ACS Web Editions allows students to search 34 ACS journals online. SciFinder Scholar allows students to search a multitude of scientific journals in all areas of science. In terms of staff, the department was reduced from 5.5 FTE to 5 FTE beginning in the fall 2004 semester.

The Learning Story

Three hallmarks characterize the typical learning experience provided through the chemistry major:

1. **Do Chemistry as Chemists Do It**
   Students use modern instruments from the first lab class in the first year; repeating experiments should be normal, not remedial. The desired outcome of an experiment is an accurate, reproducible, unambiguous result, not a predestined "right one."

2. **Modern Chemistry is Integrated**
   Chemists address problems with concepts and techniques that span the various sub-fields of chemistry. Moreover, biologists, nurses, psychologists, and physicians also regularly use these same concepts and techniques.

3. **The Main Goal of Laboratory is Tackling a New Problem Capably**
   We design experiments to develop maximum independence, not maximum coverage.

The curriculum map is included as Appendix 1. Our core curriculum introduces each student to four of the sub-fields of chemistry while providing a foundation in essential laboratory techniques. The additional courses in each emphasis then offer students more specialized technical training. Regardless of emphasis, undergraduate research is the capstone of the chemistry major at Millikin. It has four components, including the proposal, the research, a final written report, and a final oral presentation.

The proposal is part of the course CH254—Introduction to Research. The proposal must be a project suggested by a faculty member or an industrial mentor (with consent of a faculty member). The proposal includes a background section that shows careful reading of primary journals. Ideally, the research should be connected to a real-world problem.

In terms of the actual research, we look for consistent work over time. The student should try to do a project that might be presented at a meeting, especially the National Meeting of the ACS. The lab notebook is assessed to determine the quality and quantity of work. The best projects create new knowledge.

In CH482—Senior Seminar, the student writes the final report and presents the work orally. This presentation includes an explanation of the context of the work, the techniques used, the data, and what the results mean. The student is also expected to reflect on what he or she learned about chemistry in the process.

Just as the curriculum helps the department achieve goals for student learning outcomes and helps students actualize their plans of study, so too does the advising process. Advising in the Department of Chemistry facilitates and integrates reasoned choices that promote the student's growth as a person and as a major. In order to realize this mission, we try to help students:

1. Develop plans of study for successfully achieving their degree and career goals,
2. Select courses each semester to progress toward fulfilling their plans of study,
3. Use the resources and services on campus to assist in fulfilling their plans of study, and
4. Graduate in a timely manner.

At least once a semester, the student meets in person with the academic advisor to discuss fulfillment of the plan of study.

Assessment Methods

We decided that assessment of the four aspects of undergraduate research is the most informative way to assess the three learning outcome goals. The research project is the culminating event of each goal as well as the climax of each emphasis within the major. We have created rubrics for assessing the proposal, performance, and presentation of research. These rubrics are attached as Appendix 2.

Assessment Data

Department goal 1 will be assessed in CH482 using the "Final Presentation" rubric. Department goal 2 will be assessed in CH254 using the "Proposal" rubric. Department goal 3 will be assessed in CH391/491 using the "Research" rubric.

As noted above, each department learning goal will be assessed by evaluating student learning in one class. Five to 10 students from each class will be randomly selected for evaluation. As a general rule, one-half of a given class will be selected; for classes with fewer than 5 students, all students in the class will be evaluated; for classes with greater than 20 students, 10 will be randomly selected.

The grading rubrics used to assess each learning goal have three categories: Excellent, Adequate, and Nominal. The range of points possible on each rubric is 2-14. A student ranked "adequate" on all evaluative items would have a numeric score of 8. All students should be ranked "adequate" (i.e., have a minimum score of 8 on each rubric) if the department goals are being achieved. Realistically, however, there may be students, for a variety of reasons, who are ranked less than "adequate". Considering the small sample

sizes typically available in a given class, the following assessment criteria will therefore be used to evaluate student progress in achieving department learning goals:

> "Green light" (an acceptable level or clearly heading in the right direction and not requiring any immediate change in course of action): 80% or more of the students ranked "adequate" or "excellent";
> "Yellow light" (not an acceptable level; either improving, but not as quickly as desired or declining slightly. Strategies and approaches should be reviewed and appropriate adjustments taken to reach an acceptable level or desired rate of improvement): 60% to 80% of the students ranked "adequate" or "excellent"; and
> "Red light" (our current status or direction of change is unacceptable. Immediate, high priority actions should be taken to address this area): fewer than 60% of the students ranked "adequate" or "excellent".

For reporting purposes, a rubric numeric score of 13-14 will be considered "excellent"; a score of 8-12 will be considered "adequate"; and a score less than 8 will be considered "nominal".

Assessment data are listed in the tables below.

Table 1.

Department Goal 1: Demonstrate the skills to solve problems and communicate through writing and speaking.

Rubric Category	Percentage of students in category
Excellent	40
Adequate	40
Total of above (used for rating)	80
Nominal	20
Number of students evaluated	5
Average numeric score	11.0

Rating for goal 1: "Green light".

Table 2.

Department Goal 2. Discover how to integrate and apply knowledge and skills both within the chemistry community and between chemistry and other disciplinary communities.

Rubric Category	Percentage of students in category
Excellent	52
Adequate	31
Total of above (used for rating)	83
Nominal	17
Number of students evaluated	12
Average numeric score	10.6

Rating for goal 2: "Green light".

Table 3.

Department Goal 3. Develop the capacity to address real-world scenarios in which chemistry plays a role.

Rubric Category	Percentage of students in category
Excellent	43
Adequate	57
Total of above (used for rating)	100
Nominal	0
Number of students evaluated	7
Average numeric score	11.4

Rating for goal 3: "Green light".

Table 4.

Year-by-Year Comparisons.

Year →		**2006**	**2007**	**2008**	**2009**
Goal ↓					
1	Rating percentage	75	83	89	80
	"Color" rating	Yellow	Green	Green	Green
2	Rating percentage	66	100	100	83
	"Color" rating	Yellow	Green	Green	Green
3	Rating percentage	88	100	80	100
	"Color" rating	Green	Green	Green	Green

Ratings: ≥ 80% = Green; 60% - 80% = Yellow; ≤ 60% = Red

Analysis of Assessment Results

For the 2008-2009 academic year, student learning for all three of our learning goals was assessed at the "green light" level (an acceptable level or clearly heading in the right direction and not requiring any immediate change in course of action). We are, of course, pleased with these results. This is the third consecutive year in which student learning has been at the "green light" level.

Academic year 2005-2006 was the first year we did formal assessment of student learning. Student learning that year was assessed at the "yellow light" level (not an acceptable level). In succeeding years, we have made conscious efforts to improve student learning. We believe these efforts are reflected in the acceptable level of learning in the past three years for all three department learning goals.

On a less than positive note, we continue to observe that the quality of student writing remains dismal across the board. We recognize that despite the positive assessment of student learning, this is one area where we must and will continue to work with students to strengthen their skills.

While we are pleased that our students achieved an acceptable level of learning on all three of our learning goals, we know that we cannot rest on our laurels. We continually evaluate our curriculum, keeping two areas foremost in our evaluation: 1. Are we delivering a quality education to our students? and 2. How well do our students learn?

Quality

We are confident in the quality of our program. Our program is accredited by the Committee on Professional Training of the American Chemical Society—the benchmark of a quality chemistry program. Our graduates leave Millikin and go onto successful and distinguished professional careers. All eight of our May graduates either have jobs or have been accepted to professional or graduate school. Considering the current economic conditions, it is remarkable that all of our graduates have positions upon graduation. We believe this is another example of the quality of our program. Furthermore, the university recently undertook an internal self-study project. The results of that study ranked the Department of Chemistry as a "high quality" program, one of the few departments in the university to be so designated. We therefore know our students gain a quality education that prepares them for professional success and that our program is a high quality program.

We conduct exit interviews with each of our graduating seniors. We ask students to be prepared to discuss the following six questions (students are given the questions in advance):

1.) What will you be doing one year from now?
2.) What will you most remember about your experience as a chemistry major five years from now?

3.) What, if anything, would you do differently if you had to complete your degree all over again?
4.) How would you advise a new chemistry student?
5.) What are the strengths of the chemistry program?
6.) What aspects of the chemistry program need improvement?

Students are open and honest in their responses to these questions. The overall message we receive from students is "keep doing what you have been doing". Even so, students often offer specific suggestions for improvements in the department, which we take to heart. Students have commented that our curriculum does not give students any historical perspective on the field of chemistry. We therefore modified CH482, Chemistry Seminar, to incorporate the reading of more historical texts. In recent years, we have read texts such as "Mendeleev's Dream", "Uncle Tungsten", "Einstein's Luck", and "Collapse". Students expressed a desire to have more exposure to forensic chemistry, so CH253, Intermediate Lab III, now includes one or two forensic chemistry projects each year.

Learning

In addition to the learning goals and assessment measures described in this report, we also use additional measures to assess student learning in the chemistry program. We continually monitor and evaluate these measures of student learning. We monitor the quality of our students' writing on formal laboratory reports, research proposals, and research reports. We see a downward trend in the quality of writing—a situation admittedly not unique to chemistry, but disturbing nonetheless. We encourage students to take advantage of the resources available at Millikin's Writing Center, and mentor students one-on-one. We administer standardized exams such as those developed by the American Chemical Society's Examinations Institute and the Educational Testing Service Major Field Test in Chemistry. We find that our students typically score below the 50^{th} percentile on such standardized exams. We view the standardized exams as a measure of our students' long-term learning, and are concerned with the relatively poor performance of our students on these exams. We will devote more effort in the future to improving our students' long-term learning while still maintaining their excellent showing on our learning goals.

Improvement Plans

As noted above, one area we intend to work on is improving students' long-term learning. We administer the ETS Major Field Test in Chemistry in our seminar course, CH482. In the past, we administered the test at the end of the course. Students merely had to take the exam—there was no incentive for students to do well on the exam, nor was there a penalty for doing poorly on the exam. This year, we administered the test near the beginning of the course. We also instituted a minimum score students were required to achieve in order to "pass" the test. If students did not pass the test on their first attempt, they were required to work with a faculty member on remedial proficiencies before taking the exam a second time. If students did not pass the exam on their second attempt, the cycle repeated, and students were allowed to take the exam a third and final time.

The ETS exam is scored on a scale of 120-200. We set 140 as the "passing" level. Student results were as follows:

Table 5.
"Passing" Grades vs. Number of Attempts on the ETS Major Field Test in Chemistry

Year →	**2008**	**2009**
Attempts ↓		
Percent passing on 1st attempt	39	44
Percent passing on 2nd attempt	22	33
Percent passing on 3rd attempt	11	12
Percent not passing	28	11

The class of 2009 collectively did a better job on the ETS exam than did the class of 2008. All but two students from 2009 passed the exam on the first or second attempt. Of the two students who took the exam a third time, one of them overcame her severe case of "senioritis" to pass the exam; the second student improved her score to 138, just below our criterion for passing. We believe, nevertheless, that all students should pass after their second attempt. We will therefore develop plans to work and tutor students more closely so future students will successfully complete the exam after no more than two attempts.

In sum, our students are learning well. We must continue to do the things that have been successful for our students. We will therefore continue to do the same things we have done in the past with the "tweaks" identified above. We will, of course, continue to collect data in the coming years to be better able to identify trends that may need to be addressed in more depth.

Appendix 1: Curriculum Map for Chemistry

University Goals

1. Professional success
2. Democratic citizenship in a global environment
3. A personal life of meaning and value

Department Goals

1. Demonstrate the skills to solve problems and communicate through writing and speaking.
2. Discover how to integrate and apply knowledge and skills both within the chemistry community and between chemistry and other disciplinary communities.
3. Develop the capacity to address real-world scenarios in which chemistry plays a role.

Curriculum Map (Lecture/Lab) (**Bold** = Chemistry core courses)

Year	Dept. Goal 1	Dept. Goal 2	Dept. Goal 3
1	CH121/**151** **CH224/CH152**		
2	**CH232/CH253** **CH301/251** **CH302**/CH252		
3	**CH303**/CH351 CH304 CH432	**CH254** CH331/CH354	**CH391-392**
4	CH353 CH406 CH420/CH352 **CH482**	**CH482**	CH470 **CH491-492**

Appendix 2: Evaluation Rubrics for Undergraduate Research

The proposal: grading done by faculty member teaching Introduction to Research

	Excellent	Adequate	Nominal
Process	**5 points]** A thorough explanation of previous work to a clear study question followed by analysis of previous work to synthesis into a coherent proposal.	**[3 points]** Shows some evidence of the process: explanation to conjecture to analysis to synthesis but incomplete.	**[1 point]** Restates some general ideas or issues but shows no evidence of analysis.
Connection	**[3 points]** A good proposal has a history. This includes your personal experience, it has a real-world context, and it has a connection to previous work both at Millikin and in the literature.	**[2 points]** Shows you understand the history of the proposal by examining some of your own experiences in the past as they relate to the proposal but otherwise incomplete.	**[1 point]** Minimal connections made.
Readings	**[4 points]** In-depth synthesis of thoughtfully selected aspects of readings related to the proposal. The readings are significant and appropriate at the college level. While you may use data and primary texts collected from the internet, the majority of readings are from library sources. Makes *clear* connection between what is learned from readings and the proposal.	**2 points]** Goes into more detail explaining some specific ideas or issues from readings related to the topic. Makes general connections between what is learned from readings and the topic.	**[1 point]** You show some evidence of reading about the topic and are able to state some general ideas or issues from readings related to the topic. But there is no evidence of library research beyond the class textbook, secondary sources and the internet.
Grammar	**[2 points]** No spelling or grammar errors.	**[1 point]** Few spelling and grammar errors.	**[0 points]** Many spelling and grammar errors, use of incomplete sentences, inadequate proof reading.

Research: evaluation by faculty mentor using notebook

	Excellent	Adequate	Nominal
Quantity	**[5 points]** You work consistently over the entire research period with clear evidence of significant weekly work. You consistently report to faculty mentor.	**[3 points]** You work consistently most of the time but miss from time to time	**[1 point]** You try to cram the work into a short period
Quality	**[3 points]** You work efficiently with some measure of success. Your work is worthy of submission to an off-campus conference	**[2 points]** You have some success but not at the level worthy of an off-campus conference	**[1 point]** Work is not worth crowing about.
Notebook	**[4 points]** Notebook is clearly written and contemporaneous.	**2 points]** Notebook is contemporaneous but hard to follow.	**[1 point]** Your notebook is incomplete and a mess.
Safety	**[2 points]** You consistently use safe practice and clean up your work area.	**[1 point]** You consistently use safe practice but leave a mess behind.	**[0 points]** You work in an unsafe manner.

Final Presentation: written and oral report of results

	Excellent	Adequate	Nominal
Report	[5 points] A report having quality that might be submitted to a research journal. Includes background, data and methods, results, and discussion. Includes suggestion for further work.	[3 points] A good report but missing some aspect of an excellent report	[1 point] A report having minimal value
Oral Presentation	[5 points] Clear, confident presentation. Audience questions are answered in a way to illustrate a complete knowledge of the topic.	[3 points] A good presentation but lacking clarity or confidence.	[1 point] An awkward, weak presentation but a presentation made nevertheless.
Reflection	[2 points] A valuable reflection on the complete undergraduate chemistry experience.	[1 point] Some attempt at reflection but incomplete	[0 points] No reflection
External presentation	[2 points] Presented results at an off-campus conference or meeting	[1 point] Presented a good poster at the Millikin undergraduate research symposium	[0 points] No presentation

Appendix 3: Student Learning Evaluation Forms

Millikin University
Department of Chemistry
Student Learning Evaluation

Evaluation of: Department Goal 1.
"Demonstrate the skills to solve problems and communicate through writing and speaking."
Item evaluated: Final Presentation (written and oral report of results)
Student name:
Date of evaluation:
Evaluation by: Faculty member teaching Chemistry Seminar and/or Faculty Mentor
Faculty name:

Item	Criteria			Student Score
	Excellent	Adequate	Nominal	
Report	[5 points] A report having quality that might be submitted to a research journal. Includes background, data and methods, results, and discussion. Includes suggestion for further work.	[3 points] A good report but missing some aspect of an excellent report	[1 point] A report having minimal value	
Oral Presentation	[5 points] Clear, confident presentation. Audience questions are answered in a way to illustrate a complete knowledge of the topic.	[3 points] A good presentation but lacking clarity or confidence.	[1 point] An awkward, weak presentation but a presentation made nevertheless.	
Reflection	[2 points] A valuable reflection on the complete undergraduate chemistry experience.	[1 point] Some attempt at reflection but incomplete	[0 points] No reflection	
External presentation	[2 points] Presented results at an off-campus conference or meeting	[1 point] Presented a good poster at the Millikin undergraduate research symposium	[0 points] No presentation	
Total Points (14 max.)				

Millikin University
Department of Chemistry
Student Learning Evaluation

Evaluation of: Department Goal 2.
"Discover how to integrate and apply knowledge and skills both within the chemistry community and between chemistry and other disciplinary communities."
Item evaluated: The research proposal
Student name:
Date of evaluation:
Evaluation by: Faculty member teaching Introduction to Research
Faculty name:

Item	Criteria			Student Score
	Excellent	Adequate	Nominal	
Process	**[5 points]** A thorough explanation of previous work to a clear study question followed by analysis of previous work to synthesis into a coherent proposal.	**[3 points]** Shows some evidence of the process: explanation to conjecture to analysis to synthesis but incomplete.	**[1 point]** Restates some general ideas or issues but shows no evidence of analysis.	
Connection	**[3 points]** A good proposal has a history. This includes your personal experience, it has a real-world context, and it has a connection to previous work both at Millikin and in the literature.	**[2 points]** Shows you understand the history of the proposal by examining some of your own experiences in the past as they relate to the proposal but otherwise incomplete.	**[1 point]** Minimal connections made.	
Readings	**[4 points]** In-depth synthesis of thoughtfully selected aspects of readings related to the proposal. The readings are significant and appropriate at the college level. While you may use data and primary texts collected from the internet, the majority of readings are from library sources. Makes *clear* connection between what is learned from readings and the proposal.	**2 points]** Goes into more detail explaining some specific ideas or issues from readings related to the topic. Makes general connections between what is learned from readings and the topic.	**[1 point]** You show some evidence of reading about the topic and are able to state some general ideas or issues from readings related to the topic. But there is no evidence of library research beyond the class textbook, secondary sources and the internet.	
Grammar	**[2 points]** No spelling or grammar errors.	**[1 point]** Few spelling and grammar errors.	**[0 points]** Many spelling and grammar errors, use of incomplete sentences, inadequate proof reading.	
Total Points (14 max.)				

Millikin University
Department of Chemistry
Student Learning Evaluation

Evaluation of: Department Goal 3.
"Develop the capacity to address real-world scenarios in which chemistry plays a role."
Item evaluated: Research (evaluation by faculty mentor using notebook)
Student name:
Date of evaluation:
Evaluation by: Faculty mentor
Faculty name:

Item	Criteria			Student Score
	Excellent	Adequate	Nominal	
Quantity	**[5 points]** You work consistently over the entire research period with clear evidence of significant weekly work. You consistently report to faculty mentor.	**[3 points]** You work consistently most of the time but miss from time to time.	**[1 point]** You try to cram the work into a short period.	
Quality	**[3 points]** You work efficiently with some measure of success. Your work is worthy of submission to an off-campus conference.	**[2 points]** You have some success but not at the level worthy of an off-campus conference.	**[1 point]** Work is not worth crowing about.	
Notebook	**[4 points]** Notebook is clearly written and contemporaneous.	**[2 points]** Notebook is contemporaneous but hard to follow.	**[1 point]** Your notebook is incomplete and a mess.	
Safety	**[2 points]** You consistently use safe practice and clean up your work area.	**[1 point]** You consistently use safe practice but leave a mess behind.	**[0 points]** You work in an unsafe manner.	
Total Points (14 Max.)				