Millikin University
Student Learning in the Chemistry Major

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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. 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. Students in the Department of Chemistry demonstrate performance learning in the three stages of an undergraduate research project: proposal, performance, and presentation. This activity requires the synthesis of all three learning outcome goals and therefore is the easiest to assess uniformly. Excellent undergraduate research characterizes excellent chemistry programs.

We created a rubric for assessing each component of undergraduate research: proposal, performance, and presentation (oral and written). 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.

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Learning Goals

Millikin students thrive through our unique approach to performance learning. In addition to a solid foundation in the theory of a given field, Millikin students gain practical, hands-on experience in their fields of study. Students in the Department of Chemistry demonstrate performance learning in the three stages of an undergraduate research project. Our students learn how to plan and communicate their plan for research by writing a proposal. They learn to conduct research by performing research. They learn how to communicate their results through written and oral presentations. We want our students to learn how to do chemistry the way chemists do it, and we accomplish that by having our students chemistry the way chemists do it.

The culmination of performance learning for students in the Department of Chemistry is presentation of their research to an external audience. Two chemistry majors graduated in December 2014, and eight chemistry majors graduated this May. Three of the ten students presented their research at the 2015 national convention of Sigma Zeta National Science and Mathematics Honor Society, and one of these students won a 2014-2015 Sigma Zeta research grant for her work. Two of the students also presented their research at the 249th national meeting of the American Chemical Society. Another student presented his research at the annual meeting of the Illinois State Academy of Science. Eight students presented their research at the 2015 Millikin University Undergraduate Research Poster Symposium, and four of them received awards for their posters, including the overall first place award, two second place awards, and a third place award. In addition, a senior physics major, more than 50% of whose research was in chemistry, presented at both the Sigma Zeta national convention and the Millikin poster symposium, where she won a first place award.

The Department of Chemistry further 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 normally 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. (The department did not have a full-time analytical chemist during the 2014-2015 academic year.) 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, . 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 the 83,000-square-foot Leighty-Tabor Science Center, which opened in the spring 2002 semester. Approximately half of our graduates pursue advanced degrees.

Students can only thrive when they are mentored by an active and engaged faculty. Fortunately, that is the case in the Department of Chemistry. In the past year, three faculty members co-authored a peer-reviewed note about the international summer research program in Taiwan in cooperation with Tunghai University. Two faculty members successfully obtained Project SEED funding from the American Chemical Society to enable economically-disadvantaged local high school students to perform research at Millikin. The same two faculty members attended the Sigma Zeta National Convention. One faculty member established a research collaboration with a professor at Washington University in St. Louis and presented at a conference in Philadelphia on his incorporation of computer programming for problem solving in an advanced chemistry course. One faculty member helped the Millikin University Institute for Science Entrepreneurship get approval to launch a program in Clinical Nuclear Science, attended the 249th National Meeting of the American Chemical Society, and was named the first John A. Leighty Distinguished Professor, continuing a tradition of excellence in teaching and research that is a hallmark of the Department of Chemistry.

The department has experienced a “changing of the guard” in terms of faculty. The department conducted a successful search in fall 2014 for an analytical chemist and will welcome Kyle Knust to the faculty in August.

Furthermore, the position of Laboratory Support Specialist, which began with the Fall 2011 semester, was eliminated for the 2015-2016 academic year due to budget cuts. This person taught half-time and worked half-time setting up teaching labs, maintaining the chemical inventory and storeroom, and assisting with the development of curricular materials. Even before the loss of this position, the department hired nearly 3 FTE adjunct instructors. Therefore, a short-term goal of the department is to recover one full-time position as soon as budget conditions permit and to add a sixth tenure-track position within five years. Another short-term goal in the area of staffing is to secure a change in status from part-time to full-time for the administrative assistant who supports the department and the pre-professional programs.

In terms of curriculum, our most recent initiatives have been driven by forces external to our department. For example, a unilateral decision by the faculty of another science department as to how to advise their students to select courses resulted in the decimation of the enrollment in CH131—Accelerated General Chemistry. Consequently, we will not offer the course in fall 2015. Also, in response to the recent budget crisis, the department decided to begin offering CH420—Instrumental Analysis and CH406—Advanced Inorganic Chemistry on an alternating-year basis instead of offering each on an annual basis. In addition, the retirements of two senior faculty members coupled with the loss of the Laboratory Support Specialist position have eliminated much of the faculty expertise with respect to teaching Block General Chemistry, so the future of that course is tenuous. These changes, and the hiring of two junior faculty members in three years, are inspiring us to undergo a thorough curriculum review in the near future.

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. Working in cooperation with the staff of Staley Library, we added two new resources in 2008 and 2009 for students to use in research: ACS Web Editions and SciFinder web version. ACS Web Editions (Academic Core Package) allows students to search 34 ACS journals online and retrieve full-text articles from 15 journals. SciFinder allows students to search a multitude of scientific journals in all areas of science.

With respect to the summer research program in Taiwan in cooperation with Tunghai University, one of our long-term goals is to continue this relationship and increase the number of students participating in the program. Three students participated in the program in the summer of 2011, and 5 students participated in the summer of 2012. Five students participated in the summer of 2014.

Approval by the Committee on Professional Training of the American Chemical Society; excellent facilities; a dynamic curriculum that evolves to meet the needs of our students; students demonstrating performance learning; an active and engaged faculty. What does it add up to? According to information

from the Career Center, a **B M P M MM N** for chemistry graduates from 2004-2014.

The Learning Story

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

B CMN M B CMM N
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."

B CMN CM NA N
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.

. B C ! N CM C A

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 three components, including the proposal, the research, and final written and oral presentations.

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 three stages of undergraduate re

“adequate”. Considering the small sample sizes typically avail

Total of above (used for rating)	100
Nominal	0
Number of students evaluated	5
Average numeric score	12.2

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	0
Adequate	80
Total of above (used for rating)	80
Nominal	20
Number of students evaluated	5
Average numeric score	9.5

Rating for goal 3: “Green light”.

Table 4.

Year-by-Year Comparisons.

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1	Rating percentage	100	100	75	100
	“Color” rating	Green	Green	Yellow	Green
2	Rating percentage	84	100	100	100
	“Color” rating	Green	Green	Green	Green
3	Rating percentage	83	100	62.5	80
	“Color” rating	Green	Green	Yellow	Green

Ratingp

Analysis of Assessment Results

For the 2014-2015 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). This is the ninth consecutive year in which student learning for goal #2 has been at the “green light” level. This is the eighth time in nine years in which student learning for goals #1 and #3 has been at the “green light” level. Although we are pleased with these results, we view them as still having room for improvement. As we have done in every year since we began the assessment process, we have made (and continue to make) conscious efforts to improve student learning.

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.

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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. Recently, students have expressed that they would have liked more detailed guidance about the graduate school application process and more preparation for the Graduate Record Exam (GRE), so we are looking at revising assignments and developing new resources for those areas.

However, quality is more than a modern and up-to-date curriculum. To complete the quality package, that curriculum must be supported by modern and up-to-date instrumentation. In the Modernization Report requested by Dean Randy Brooks in 2013, we documented the (desperate) need to update our instrumentation holdings. An article in the Council on Undergraduate Research CUR Quarterly (“Guidance for Entering Academics in Organic Chemistry”, McLaughlin, E. C. et al., Summer 2013, pp. 41-48) lends further credence to the important role infrastructure and internal support play in the quality of a chemistry program. Two selected quotes from the article:

> “It is not uncommon for certain chemistry programs to have over $500,000 invested in instrumentation…Accordingly, the dollar support earmarked for equipment maintenance by the institution sends a clear message to both entering students and faculty.”
>
> “If the institution expects the potential faculty member to be visible in research, that institution will supply support to assist in the establishment of a research program. At predominantly undergraduate institutions, these amounts vary (and typically range from $25,000 to $50,000)…”

In the last year, the Chemistry Department, thanks to the Leighty funds for equipment modernization, has acquired over $87,000 worth of new equipment that will be used in our curriculum and in research. While we greatly appreciate these acquisitions, we want the university to understand that ongoing maintenance and upkeep is a significant investment, too. In order for the Department to continue to “deliver on the promise of education” and deliver a high quality program to our students, the level of annual support from the university must dramatically increase.

One aspect of the search for an analytical chemist that helped make it successful was the start-up package we were able to offer. In a break with tradition, the department offered $25,000 spread over three years. Each candidate who visited campus for an interview found this amount to be more than adequate, as did all but one of the candidates who were interviewed by phone. The chemistry faculty are appreciative that the Dean and Provost supported this idea.

Learning

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

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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

Research: evaluation by faculty mentor using notebook

Excellent

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

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 C N M** A thorough explanation of previous work to a clear study question followed by analysis of previous work to synthesis into a coherent proposal.	**5 C N M** Shows some evidence of the process: explanation to conjecture to analysis to synthesis but incomplete.	**5 C N** Restates some general ideas or issues but shows no evidence of analysis.	
Connection	**5 C N M** 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.	**5 C N M** 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.	**5 C N** Minimal connections made.	
Readings	**5 C N M** 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 connection between what is learned from readings and the proposal.	**C N M** Goes into more detail explaining some specific ideas or issues		